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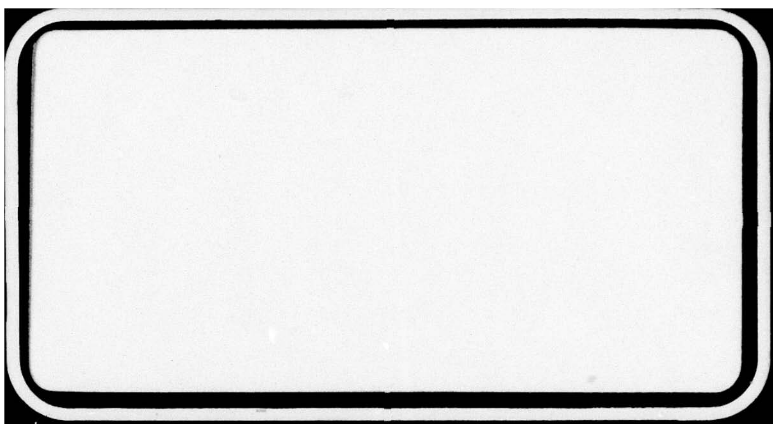

LEVEL III

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[redacted] CANADIAN DIVING SYMPOSIUM (3rd)

HELD AT

DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL

MEDICINE

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USES AND DEVELOPMENTS IN REMOTELY CONTROLLED UNDERWATER WORK VEHICLES IN CANADA

By

J.B. McBeth

International Submarine Engineering

INTRODUCTION

In the last few years remotely controlled undersea vehicles have shown a great surge in capabilities and popularity. There are now in excess of 70 vehicles operating worldwide. These vehicles have similar performance to manned submersibles in that they are self propelled, utilize various ballast systems, can be equipped with manipulators and can carry a wide array of navigation systems. The major difference is that they are controlled from the surface through an umbilical which also supplies power. At this time, International Submarine Engineering Ltd. (I.S.E.) is the only Canadian company actively designing, building, and marketing remote vehicles. I.S.E. vehicles are now being operated in Canada, the U.S.A., and the United Kingdom. Operators include the Canadian Centre for Inland Waters, Sonar Marine a B.P. Subsidiary, J. Ray McDermott Inc., Martech International, and Ocean Systems. Most of the present work relates to support of offshore petroleum activities.

HISTORY

During the boom in manned submersible development in the late 60's very few unmanned vehicles were developed for the commercial market. Initial designs such as the U.S. Navy CURV unmanned submersible were produced under military funding. It was not until the early 70's that unmanned vehicles started entering the offshore market. The first vehicle to sell in any quantity was the RCV-225 originally developed by Hydroproducts under a U.S. Navy contract and introduced to non-military users in approximately 1973. To this time, Hydroproducts had sold the largest number of unmanned vehicles in the world.

The second largest producer of unmanned vehicles is International Submarine Engineering Ltd. (I.S.E.) in Port Moody, British Columbia. I.S.E. (formerly "McElhanney Offshore Surveying & Engineering Ltd.") was formed in September of 1974. Their first Tethered Remotely Operated Vehicle (TROV) was completed in 1975.

A brief summary of the ISE build programs is provided in Table 1.

TECHNICAL DESCRIPTION

Unmanned submersibles come in a variety of shapes, sizes, performance capabilities and depth ratings. The smallest can be picked up by a man, and the largest weigh several thousand pounds. They do, however, have several common characteristics. Instead of utilizing one large pressure hull, electronics, cameras and electrical distribution systems are usually housed in small individual pressure housings. Syntactic foam is often used as the main source of buoyancy and in some cases such as the small RCV-225 is molded to form the basic support structure. In larger vehciles such as TROV, an open framework is used to achieve flexibility in mounting components. Most vehicles operate on AC power delivered through the umbilical. In order to reduce umbilical size and complexity, control signals are usually multiplexed. In manned systems, pressure hulls play a significant role in increased cost and design requirements with increasing depth. However, in unmanned vehicles, since no complex pressure hulls are usually involved, depth rating is dictated more by size, weight, and umbilical handling constraints. In general, system size increases with depth capability. Vehicle size increases to accommodate more and denser syntactic foam and more powerful propulsion systems to account for increased umbilical drag. Also, the surface winch and handling gear must be larger.

Areas where designs vary markedly include control, propulsion, manipulation and navigation systems. In some cases microprocessors are used for all control and multiplexing functions. Other control systems such as those utilized by I.S.E. are based on CMOS but may use dedicated microprocessors for individual control functions. Propulsion systems vary in configuration and use either electric or hydraulic motors. Manipulators, if available, may be either electrically or hydraulically driven. Hydraulic systems are more common on the larger vehicles such as TROV which utilizes hydraulics for the manipulators, tools, camera pan and tilts and thruster pitch controls. Navigation systems also vary widely. The larger open frame vehicles, however, have few constraints relating to systems that can be fitted. The wide variations in available designs result from differences in design phylosophy as well as the wide range of potential applications. There is no design that can be considered a panacea.

Specifications for the TREC and TROV models manufactured by I.S.E. are provided in Table 2.

ADVANTAGES OF REMOTE VEHICLES

Advantages of unmanned vehicles over alternate systems such as manned submersibles or divers include lower costs, safety, power and endurance. There are, of course, comparative disadvantages relating to such things as umbilical entanglement problems and the fact it is simply not possible in some instances to replace all of a person's sensory inputs that can be utilized when they are actually at the work site. Recent operations have, however, indicated that a significant proportion of the work presently being done by manned systems can be accomplished by suitably equipped remote vehicles.

The purchase price of a remote vehicle is much less than a comparably equipped manned submersible but there are other, sometimes even more important, advantages to the operator. First of all, operating costs are also much less. Transportation costs of smaller systems are significantly reduced which is important considering the worldwide market for operations. Surface handling systems are greatly simplified for the smaller vehicles and much smaller ships can be utilized. This allows the operator to quickly mobilize the system on convenient ships of opportunity anwhere in the world. The operators do not have to enter into expensive long term charters of ships. Also, down time between jobs is short due to the fast demobilization/mobilization capability. These factors have contributed to a large increase in the market for vehicle operations in short term charters and in work in remote locations of the world where use of manned systems had previously been unfeasible in terms of both time and costs.

Perhaps one of the most significant advantages of remote vehicles is simply that since they are not manned there is no risk to human life. This is significant in many ways. Life support systems and redundant systems are not required. Additionally, approval by authorities such as the American Bureau of Shipping or Lloyds is not required for insurance purposes. Higher acceleration loads are allowable during surface handling thus allowing more flexibility in launch/recovery systems. Payload requirements are greatly reduced resulting in much smaller, more compact vehicles while still carrying comparable instrumentation to the manned submersibles. Also, in the event of an accident the cost of repairing or even replacing the diving portion of the vehicle is much less than a manned submersible. Even more significant, there is no requirement for a massive rescue effort with its associated costs, bad publicity and perhaps the ultimate tragedy of actual loss of life.

The potential for loss of life in a submersible accident has caused many offshore companies to back away from the use of manned submersibles in recent years. In some cases where manned submersibles are

still used, the customers will not allow their field representatives to dive in the submersible. This results in the customer having to rely on second-hand information, after the fact. Unmanned vehicles have no limit to the number of observers on the surface and allow decisions to be made while the dive is in progress.

Unmanned submersibles have many advantages over divers relating mainly, as when compared to manned submersibles, to their lower operating costs, safety, reduced surface support requirements and fast response capabilities. These facts are well understood by the diving industry evidenced by the fact that a large percentage of vehicle sales to date have been to diving companies.

Other areas where tethered vehicles exhibit significant advantages over alternate systems are endurance and power.

The endurance of the vehicles is virtually unlimited. Complete crew changes can be made while the vehicle is working. The longest dive to date recorded by an I.S.E. vehicle is 40 hours.

Available power is not limited by battery capacity and therefore higher power levels can be used than on a manned submersible. For example, a 30 HP water jet pump has been operated on a TROV while pump sizes on manned submersibles range between 5 and 10 HP.

PRESENT USES

Most work presently being done with remote vehicles centers around simple observation. The simplest vehicles consist of a T.V. camera and thrusters for manoeuvering. These vehicles are used to survey easily located offshore structures such as platforms and risers. With the addition of an accurate navigation system, the vehicles can be used for location and observation.

An example of a task where location is required is pipeline inspection where the recording of position and bottom vs pipe depth information is just as important as the video record. The navigation systems used, such as the Honeywell RS7, read out relative position between the ship and one or more vehicles. This allows the use of live boating techniques since the ship can maintain station over the vehicle. By coupling the surface navigation system to the submersible locating system, it has been possible in recent contracts to perform a complete as-built survey of a pipeline in one pass. Time and cost savings were significant when compared to alternate systems such as using divers to place buoys on the pipe and checking depth information using the divers' Nemos.

The navigation system is also commonly used to position other objects on a location found by the vehicle. Examples are drill stem re-entries and positioning diving bells to minimize divers' bottom times.

Since there is no limit to the vehicle's bottom time, the submersible is commonly left on the bottom to observe and provide light for divers or simply to save time in relocation. The TREC vehicles produced by I.S.E. are specifically designed for the location and observation functions although recent models also have been equipped with manipulators to further expand their capabilities.

A TREC vehicle also played a part in another significant recent development in remote vehicle operations. Horton Maritime Explorations of North Vancouver, British Columbia, operated the TREC P from their submarine, the "August Picard", to demonstrate the capability of operating a remote vehicle from a submerged platform. Horton Maritime Explorations subsequently ordered a TREC vehicle with the aim of offering the service to offshore market. The advantage of this notion is that it provides a capability independent of surface weather conditions. Thus system utilization can be enhanced.

I.S.E.'s TROV is in the class of remote vehicles designed to perform a wide variety of underwater tasks in addition to basic observation and location work. Acceptance of remote vehicles in performing complex tasks using manipulators and/or sophisticated instrumentation has been slow in coming. Poor performance by some early vehicles has made many potential customers hesitant. In general, the tremendous costs of offshore operations make companies reluctant to accept anything other than proven systems. This catch 22 type problem has been overcome recently with TROV operations by demonstrating the extra capabilities while under contract to do simple survey work. Once demonstrated, TROV's capabilities are finding increased use in the latest contracts. Sonarmarine Ltd., in England, have utilized the capabilities of TROV to perform platform inspection work in the North Sea of the type previously only undertaken by divers. This involved cleaning areas of metal and handling non-destructive testing equipment. To do the work TROV was equipped with two T.V. cameras to allow the technician to work independent of the pilot. The two highly articulated manipulators are used to handle tools. Space was also provided on the pan and tilt unit for a set of stereo still cameras and strobe. A special lifting system was manufactured to allow the TROV to be lowered from the platform deck 120 feet above the water. This TROV was also provided with an additional 300 lbs. of payload to provide for carrying a large jet pump and instrument package.

Ocean Systems in Houston, Texas, have recently had their first TROV modified to increase its depth rating to 3000 feet for a deep pipeline job in the Mediterranean off Spain. It is expected that the demand for commercial vehicles capable of work in up to 8000 feet will be significant in the next few years.

An area of significance to Canadians where TROV has demonstrated an important capability is in under ice operations. The TROV, owned by the Canada Centre for Inland Waters, was used by EMR in conjunction with Panartic to conduct an experimental survey through the ice off the east coast of Melville Island in the Canadian Arctic. On this operation, in addition to the standard T.V., manipulator and navigation systems, the TROV was equipped with a 35-mm colour camera for stills, a digital echo sounder, a Klein side scan sonar and a Raytheon sub-bottom profiler. In addition to continuous records from the above instrumentation, bottom samples were obtained for both geological and biological study. Outside air temperatures during the operation were minus 45 degrees Celsius, plus wind chill factor.

One of the deeper remote vehicle work tasks undertaken to date has been manganese nodule surveys by mining companies. I.S.E. designed and manufactured at 18,000 ft. diving depth towed sled for International Nickel which has been utilized for survey work in the Pacific.

Other examples of work that has been done using unmanned vehicles are:

- Leak Detection
- Template Alignment
- Attaching Buoy and Lift Lines
- Telecommunications Cable Inspection
- Placing Explosives
- Scour surveys around rigs
- Salvage
- Rescue
- Trench Profiling
- Wreck Survey
- Directing Rock Dumping

FUTURE DEVELOPMENTS

Remote vehicle development is following the fast changing market place. As the use of remote vehicles increases, so will the variety of customer requirements. I.S.E. vehicles are in a constant state of development to meet these expanding requirements. Because of the modular design of the component systems, it has been possible to create a wide variety of configurations, sizes and depth capacities quickly and without high development costs.

Research and development efforts are increasing to produce new or improved sub-systems to meet the more sophisticated demands expected in the near future. This includes improved control and navigation systems. Both colour and stereo T.V. systems will soon be available. The use of microprocessors will be expanded to produce increasingly intelligent vehicles capable of performing more complex tasks while

simultaneously simplifying the operator's control inputs. For example, coupling the automatic pilot, auto depth and navigation systems through a microprocessor would produce a vehicle capable of performing survey work where the operator would simply input desired location or heading information. Systems for transmitting control and video signals through water are also under development with the aim being a free swimming remote vehicle.

The largest R and D project presently underway at I.S.E. is a force feedback manipulator development program. I.S.E. was awarded a grant from the Canadian Government Industrial Research Assistance Program (IRAP) to aid in the arm development. The manipulator is designated the "TASC ARM" (Tactile Articulated Spatially Correspondent Arm) bus is actually a set of sub-systems which will allow the production of an entire new group of expanded capability manipulators. The sensory nature of the manipulator control coupled with the stereo T.V. system will allow the operator to perform the increasingly complex tasks required of remote vehicles in the near future.

CONCLUSIONS

The fast paced developments and increasing use of remotely controlled vehicles is expected to continue for some time. The principal driving force behind this development will be the expanding worldwide needs of the offshore petroleum industry. However, it is probable that the vehicle's low purchase price and ease of handling will result in their increased use in the scientific community. This,coupled with the numbers of remotely controlled vehicles coming into the market place, clearly gives evidence to the fact that they have established a position in the market place and will probably enjoy an increasing market share in the future.

TABLE 1

I.S.E. BUILD PROGRAMS

a. TROV (B) for Canada Centre for Inland Waters 1975

b. TROV 01 (U.K.) 1976

c. Manipulators Deep Diving Systems (Canada). 1976

d. TROV Sonarmarine, B.P. (U.K.). 1977

e. Manipulator (Norwegian Government) 1977

f. Towed sled for the deep ocean (INCO) 1977

g. TROV 3 J. Ray McDermott Inc. (U.S.A.). 1977

h. TREC "P", International Submarine Operators (Canada) 1977

i. TROV 5, B.P. (U.K.) 1978

j. TROV 4, Ocean Systems (U.S.A.) 1978

k. TREC 1, 2 & 3, Martech International Inc. (U.S.A.) 1978

l. TREC 4, Horton Maritime Explorations Ltd. (Canada) 1978

m. TREC 5 & 6, Ocean Systems (U.S.A.). 1978

n. TREC 7, I.S.E. 1978

o. TROV M1, Ocean Systems (U.S.A.). 1979

p. TROV 6, Ocean Systems (U.S.A.) 1979

TABLE 2

The following are the general specifications for the latest configuration of I.S.E.'s TREC and TROV vehicles. It should be noted that these are not fixed configurations. There is great flexibility available in this type of vehicle design, and the following configurations simply reflect the most recent customer requirements.

TREC

LENGTH	45 inches
WIDTH	38 inches
WEIGHT	500 pounds
THRUSTERS	Four 1 H.P.
POWER	120 volts
MANIPULATORS	One 3-function
DIVING DEPTH	1,200 feet
VIEWING	Black and White Panasonic Camera in Pan and Tilt

TRO TROV S-4

LENGTH	120 inches
WIDTH	60 inches
HEIGHT	60 inches
WEIGHT	2,600 - 3,400 lbs. depending on amount of foam fitted.
DIVING DEPTH	1,200 feet
UMBILICAL LENGTH	1,500 feet
POWER SOURCE	50 KVA 440 volt 3Ø 60 HZ Diesel Generator Set Generator
VIEWING	Two Black and White Panasonic Cameras One on Pan and Tilt, one on Tilt
MANIPULATORS	4 Function 7 Function
PROPULSION	Four 7 HP 440 3Ø 60 HZ Motors with controllable pitch propellers in kort nozzles

DEVELOPMENT OF A HYPERBARIC BLOWER

By

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Nova Scotia Research Foundation

ABSTRACT

This paper describes the development of a magnetically coupled centrifugal blower used as the main gas circulator in the D.C.I.E.M. deep dive facility. The blower design had to meet the very high ambient pressure of the deep dive facility and offer high reliability and low noise. The approach undertaken was to couple a two-stage centrifugal blower built within a pressure vessel to an external electric motor via a high energy synchronous magnetic couple providing a packless coupling through the pressure vessel wall itself.

INTRODUCTION

Safety and reliability are vital parameters in all hyperbaric systems and in particular, those systems designed for human occupancy. Experimental systems which subject men or animals to high pressure require life support systems to maintain the occupants. Central to these life support systems is the environmental conditioning unit (E.C.U.) which maintains the internal atmosphere of a hyperbaric chamber in such a condition as to support life within the chamber. The E.C.U. has the function of maintaining the oxygen level of the breathing gases to that tolerable to the life form within and to remove carbon dioxide, odors, and moisture from the chamber atmosphere. The E.C.U. performs these functions by circulation of the breathing gases through suitable filters, scrubbers, moisture removers, heating and cooling systems, to maintain a comfortable, "normal", atmosphere within the hyperbaric chamber.

PRESSURE VESSEL PENETRATION

Gas circulators are required to maintain movement of the gases through the E.C.U. Work must be done on the gas to maintain circulation and a penetration of one kind or another is necessary to furnish power to the gas circulator performing this function. The penetration into the hyperbaric chamber can be made in a number of ways such as:

a. Electrical Penetration

Electrical power is coupled, via feed through connectors, into the chamber to drive an electric motor which in turn drives the gas circulator;

b. Mechanical Penetration

A rotating shaft penetrates via a dynamic seal into the hyperbaric chamber to drive the gas circulator either directly or via a gear box;

c. Canned Motor Penetration

The pressure vessel is continued between the rotor and stator of an electric motor such that the rotor of the electric motor operates within the pressure envelope while the stator is outside. The coupling being via the rotating magnetic field through a metallic barrier interposed between rotor and stator;

d. Permanent Magnet Drives

The pressure vessel is continued via a barrier separating an arrangement of permenent magnets which are coupled to one another through the metallic barrier.

The Nova Scotia Research Foundation Corporation (NSRFC) has been requested, on numerous occasions to attempt to solve some of the problems associated with coupling power through a pressure vessel. Considerable hazard exists with any system that contains an electric motor within the pressure envelope. These hazards are those associated with electric shock, fire, and toxic outgassing from overheated insulating materials. Early in our development we decided that having a motor within the diving envelope, no matter what the voltage, was unacceptable. We have therefore focused our developments in two directions, i.e., the canned motor and the permanent magnetic coupling.

CANNED MOTOR CIRCULATORS

The canned motor approach (refer to Fig. 1) has resulted in a successful gas circulator currently in use on commercial diving bells. The circulator is covered under Canadian Patent No. 1020614 to P. Taiani assigned to NSRFC. This gas circulator consists of a 750W, 3-phase electric motor, coupling power magnetically via a high strength metallic barrier to a rotor turning within the pressure envelope. The rotor is of a special design to allow the complete elimination of any insulating materials and is designed to operate at high efficiency, with a large gap between rotor and stator. The rotor in turn drives a positive displacement rotary carbon vane pump which circulates approximately 5 litres per second (actual) at 70 KPa. The gas circulated is used in turn as a prime mover for a Coanda effect air mover which multiplies the gas flow up to a minimum of 25 litres per second (actual) at pressures sufficient to drive the chamber gas through a scrubber basket. This system has operated successfully at pressures up to 45 bars ambient and will continue to scrub a constant actual volume over the working pressure range. The work done on the gas over this pressure range is proportional to the ambient density and therefore the power drawn by the electric motor increases as

gas density increases. As the power drawn from the motor increases, the internal heating also increases and a compensating cooling system has been designed utilizing the circulated gas. The design of the circulator incorporates a system in which the inlet gas is circulated over the canned portion of the stator and since the cooling effect of the gas is proportional to its density, the system tends to maintain a constant temperature over a very wide density range. As can be seen from Figure 1, the design allows the circulator to withstand both internal and external pressure allowing the unit to be mounted on the outside of diving bells immersed in the ambient seawater and is well isolated from the occupants of the diving bell.

DEFINITION OF BLOWER NEEDS

In 1976 NRSFC undertook an internal study to examine the feasibility of producing a gas circulator to meet the needs of the Defence and Civil Institute of Environmental Medicine (D.C.I.E.M.) Deep Dive Facility (D.D.F.) The D.C.I.E.M. circulator requirements were far beyond systems previously designed by this laboratory. The D.D.F. required an ambient working pressure of 172 bars, and since the gas circulator and the associated E.C.U. was to be outside the main pressure vessel of the D.D.F., the back pressure requirements for the circulator were also high, this being due to the considerable lengths of piping involved. Since the facility was designed for long term human occupancy, noise levels from the gas circulator had to be kept to an absolute minimum. The requirement for high system head and low ambient noise levels are essentially in conflict with one another, since given a constant flow of gas, the work done on the gas is proportional to the head required and in general, the noise produced by the circulator is proportional to the work done on the gas.

The target requirements for the D.C.I.E.M. blower were as follows:

Flow	-	19-24 litres per sec.
Differential Pressure Around System	-	equivalent of 92 metres of working fluid
Maximum Working Ambient Pressure	-	172 Bars
Gas Medium	-	Heliox
Gas Density	-	0.5 - 28 Kg/m^3
Work Done on the Gas at Maximum Density	-	Approx. 750 W
Noise Level	-	Less than 70dBa within the chamber.

DESIGN APPROACH AND "BLOWER STALLS"

A review of various gas circulators was undertaken and a selection was made of a two-stage centrifugal blower which was capable of handling the energy required in a minimum size. Considerable Skepticism was expressed by some blower manufacturers and many members of the diving community, stating that blowers such as these may be subject to aerodynamic stall at high gas densities. Our calculations of the dynamics of a centrifugal blower indicated that if the blower could be maintained at a constant speed, the following relationships would apply for the blower with respect to density:

Where subscript 1 refers to performance at 1 atmosphere air and subscript 2 refers to performance at any density

Then: FLOW $= Q_2 = Q_1$ (actual volume per unit time at any density)

HEAD: $H(\text{static})_2 = H(\text{static})_1 \rho_2/\rho_1$

SHAFT ENERGY: $W_2 = W_1 \dfrac{\rho_2}{\rho_1}$

Where ρ_2 is the density of the gas mix at any pressure

ρ_1 is the density at 1 atmosphere.

The above relationships apply to all gases and since shaft energy requirements are directly related to density, a suspicion suggests itself that the skepticism raised with respect to blower stall was prompted not by aerodynamic effects but perhaps those effects due to overload of the prime mover.

CHAMBER TESTS

To lay to rest any concern aroused by the skepticism with respect to aerodynamic stall, and to confirm our design parameters, NSRFC, through the co-operation of D.C.I.E.M. and the Lamson Company, operated a two-stage centrifugal blower in a chamber at D.C.I.E.M., in a pure nitrogen environment at pressures varying from atmospheric to 244 metres equivalent seawater. The density of nitrogen at this pressure is equivalent to helium at a pressure of 1695 metres equivalent seawater (169 bars). The set up for the experiment is shown in Fig. 2. A three-phase 2200W motor operating at 3500 rpm was used to drive the two-stage blower within the chamber. Pressure and flow from the outlet of the blower were measured via two manometers, one utilizing water, the other mercury. Two manometers were needed to handle the head variation with density. At high densities the blower pressure was sufficient to blow the water out of one manometer while the mercury stayed to continue to function as a pressure gauge. The flow in actual litres per second was measured via a C-prop anemometer operating as a ducted propeller such that the measurement of flow was independent of density. A remotely operated plug valve was

utilized to control the gas flow by varying the back pressure, thus, complete Q vs H (flow vs head) curves could be taken for any ambient gas density. At the same time that the flow measurements were being taken, a three-phase analyzer was used to measure the power requirements of the three-phase motor. An extensive series of tests were made within the chamber; the results of these tests strongly substantiated our initial theoretical analysis of the gas circulator and laid to rest any of our suspicions that aerodynamic stall would occur within the centrifugal blower.

MAGNETIC COUPLING

At this point we had satisfied ourselves that we had a working gas circulator but still remaining were the problems of how to effectively "can" the gas circulator to withstand the ambient working pressure of 172 bars and even more importantly how to couple the necessary mechanical power to the blower shaft through the pressure interface. Working concurrently with the blower development program, Mr. Patric Taiani, of the NSRFC's Centre for Ocean Technology, was working on the design of a permanent magnet coupling device which would allow coupling of mechanical power through a barrier capable of withstanding high pressure differentials. In the past, permanent magnet couplers have not been particularly attractive as the capabilities of magnetic materials made magnetic couplers rather inefficient, large and heavy. In recent years the advent of high energy magnetic materials such as the rare earth magnets have changed this situation quite considerably. These magnets have energy values an order of magnitude higher than the best alnico magnets available and offer coercive forces sufficient to establish high flux levels over large gap distances. Figure 3 shows a typical BH characteristic for both samarium cobalt and alnico magnets. The saturation flux density for samarium cobalt is slightly lower than the alnico material, however the coercive force is over 5 times greater. Placing magnets in a coaxial configuration as shown in Figure 4, and causing the outer cylinder to rotate will provide snychronous shaft coupling limited only by the decoupling torque between the inner and outer magnets. Utilizing rare earth magnets, the decoupling torques can be very high. For our application we require a coupling torque in excess of 5.6 Newton metres at a rotational speed of 3600 rpm. This torque level was readily obtained in a magnetic assembly of very compact dimensions (7.5 cm dia. x 5 cm) using the rare earth magnets.

GENERATION OF EDDY CURRENTS AND BARRIER HEAT

A problem arises however, once the magnetic coupler is to be used across a pressure boundary. The design demands the interposition of a pressure vessel between the rotor and stator of the magnetic couple. Under present codes this pressure vessel barrier must be metallic and therefore an electrical conductor. The barrier forms a metallic conductor, interposed between the two magnetic poles and when these poles are caused to move, a generator of electric current is established within the metal of the barrier itself. (Refer to Fig. 5.) The magnitude of

these currents is proportional to the conductivity of the barrier material, the physical dimensions of the barrier, the flux level established and the speed of rotation. The flux level and speed are defined by the energy requirements of the shaft and the barrier thickness is defined by the strength of the metal used and the working pressure. The only freedom offered to the designer is thus the tensile strength and the conductivity of the metal chosen. For this application we required a non-magnetic metal of high tensile strength in order to reduce the barrier thickness to a minimum and a high volume resistivity coupled with an excellent ability to withstand corrosion and high temperatures. The metal chosen was Hastelloy B, which offers all of the above and has a yield stress of 690 MPa and a volume resistivity of 135uN/cm. Given the best selection of barrier, since by design the flux levels and speed are very high, the eddy current losses in the barrier were still in the order of 150 watts. The only remaining solution to this problem having minimized the losses in the barrier, was to live with them and provide adequate cooling to remove the heat. The design solution of this problem was to utilize the outer portion of the rotating couple as a centrifugal blower to draw cooling air from the ambient air (1 atmosphere) and circulate it over the barrier material. This design, as described in Canadian and U.S. Patent Application Nos. 288653 and 841934 (Taiani/Marzouk), offers a well controlled barrier temperature over a very wide range of speeds and is independent of any other source for cooling. Figure 6 shows the arrangement for cooling of the barrier. The performance of this arrangement is as follows:

Speed:	3600 rpm
Torque:	6.2 Newton metres
Coupled Power:	2340W
Losses:	150W
Efficiency:	94%
Temperature Rise:	$70^{\circ}C$

FINAL DESIGN

These developments were then brought together. A pressure vessel was designed such that the scroll of the blower was carved directly into the pressure vessel halves, and the magnetic coupling arrangement was offered in at one end. This arrangement is shown in Figure 7 and Figure 8. The completed hardware can be seen here at D.C.I.E.M. in the Deep Dive Facility. The performance achieved for the flower is as follows:

Max. Working Pressure:	- 172 bars
Test Pressure:	- 259 bars
Max. Gas Density:	- 30 Kg/m^3
Max. Gas Delivery:	- 47 actual litres/sec.
Head:	- Min. 91 metres fluid @ 19 litres/sec. actual
Noise Level:	- less than 70dB @ 1 atmosphere air
Power Requirements:	- less than 2 KVA
Weight:	- approx. 300 Kg
Connections:	- 2" SAE "O" Rings
Electrical Power Requirements:	- 230/460 V 3-Phase, 60 Hz
Material Used:	- Blower Housing - steel Impellers - aluminum
Internal Hardware:	- stainless steel
Lubricants:	- Krytox
Seals:	- Viton

The laboratory acceptance tests of these units have exceeded specifications and we now are awaiting the operational performance tests here at D.C.I.E.M.

SUMMARY

This development offers a gas circulator which should combine the highly desired element of safety, reliability and long life. The use of a self cooled high energy magnetic coupling has eliminated dynamic seals which together with the selection of a centrifugal blower, having no rubbing parts, yields a potential for long trouble free service. The blower bearings are the only wearing parts within the pressure envelope, and are easily replaceable without opening of the main pressure vessel. A complete replacement of blower bearings can be accomplished in less than one half hour.

The prime objective of the NSRFC, Centre for Ocean Technology is stimulation of new business activity in the Atlantic region and it is hoped that this technology developed originally for D.C.I.E.M., will become the subject of a technology transfer to Canadian industry.

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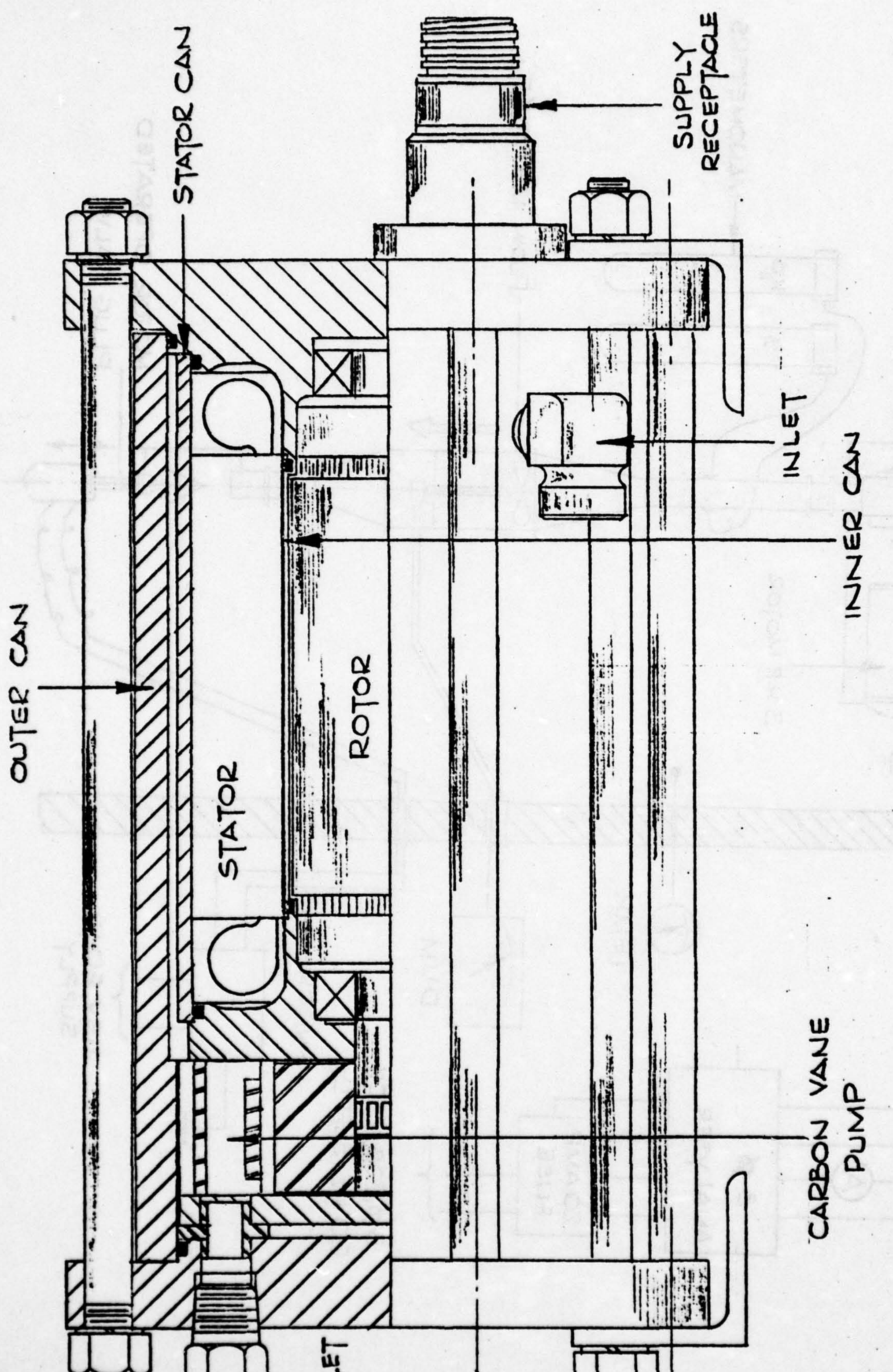
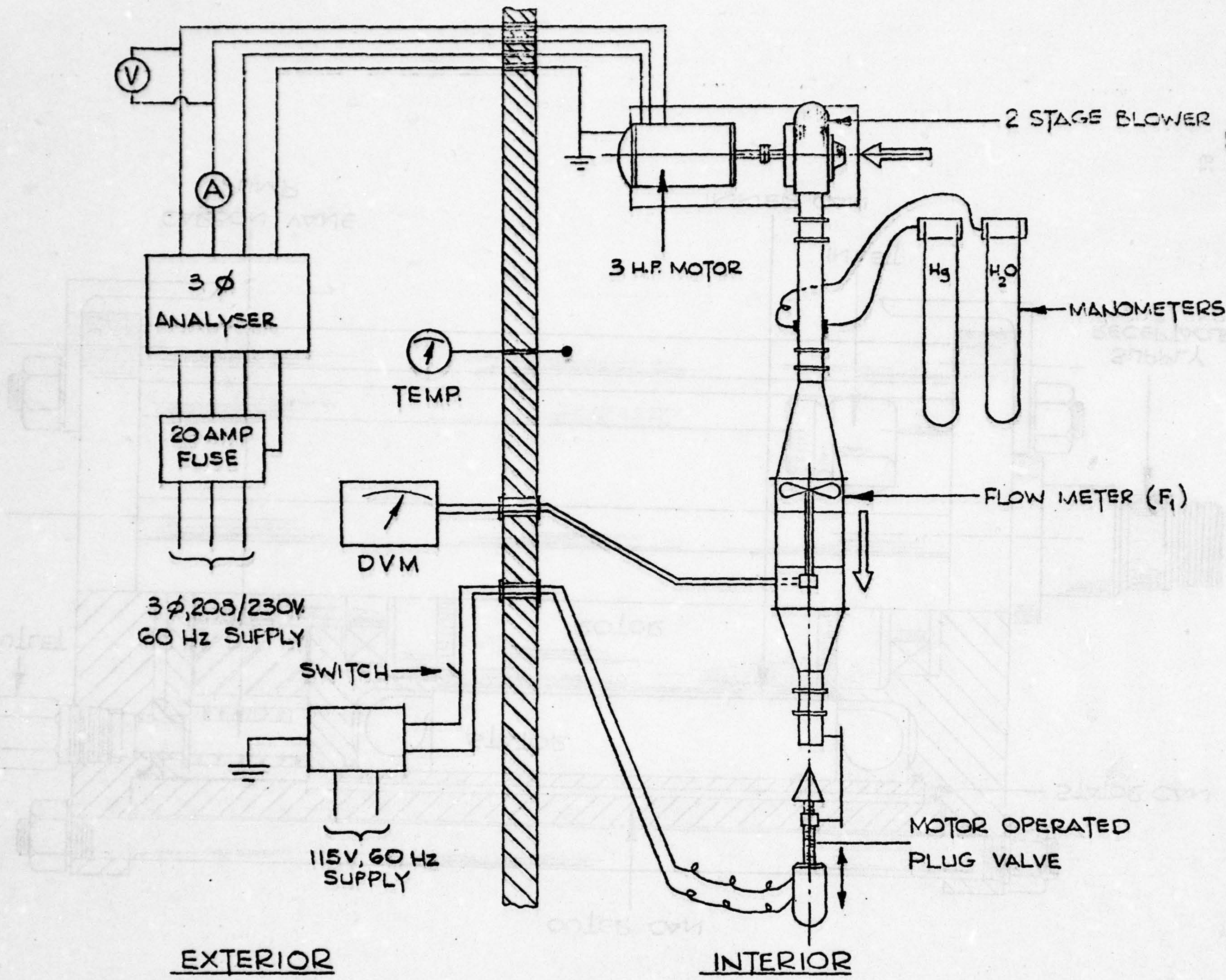
Spectra Flux Incorporated;

Patterson Industries Limited.

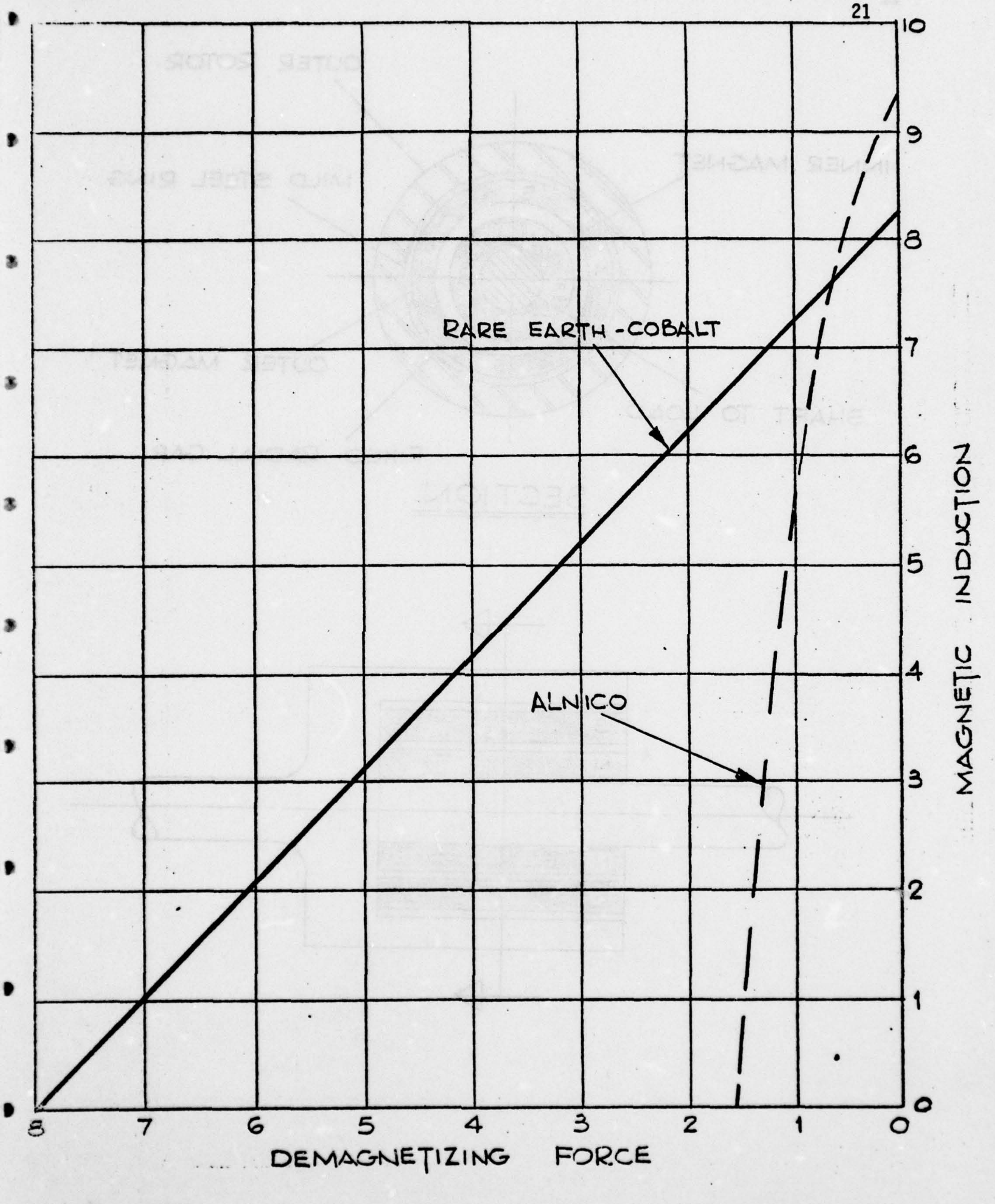


CANNED MOTOR FIG. 1

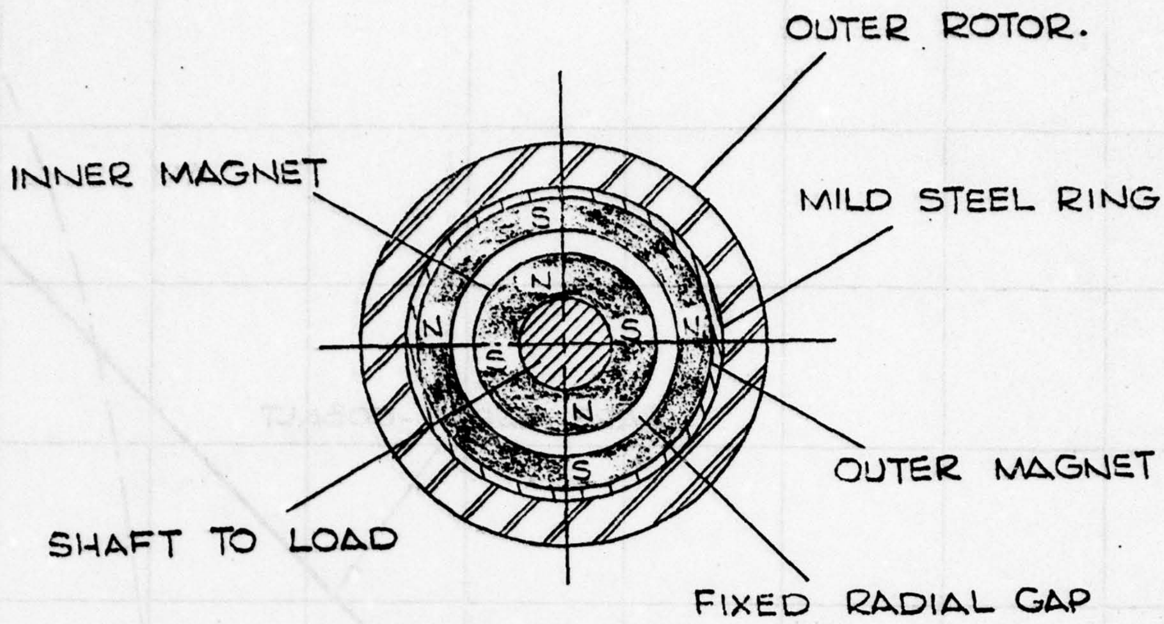


TEST SET-UP

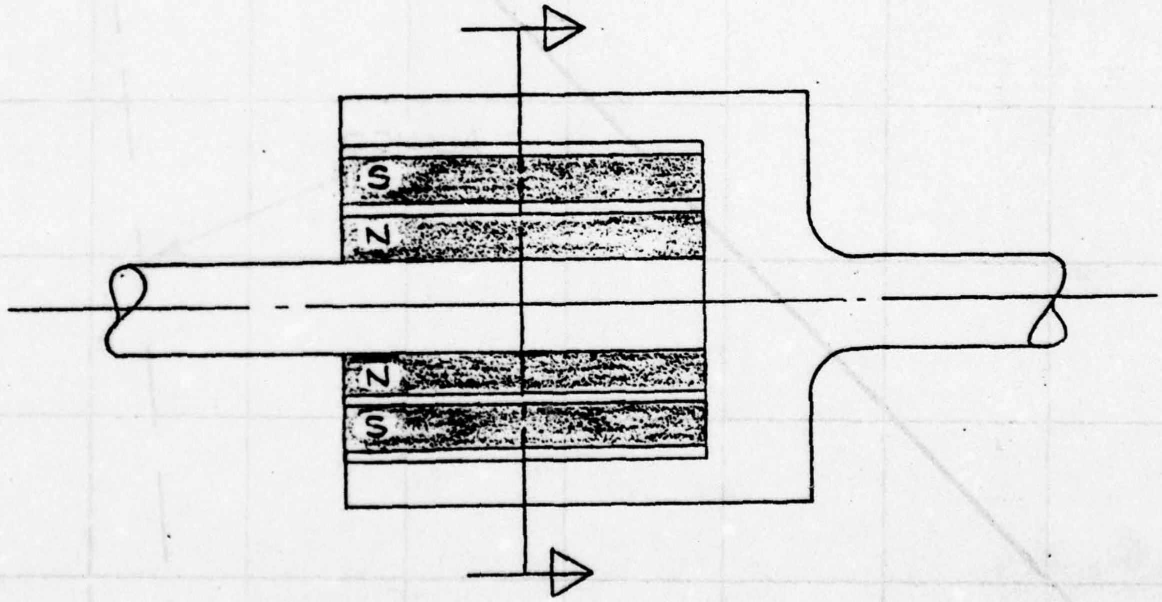
FIG. 2



B H CURVE FIG. 3

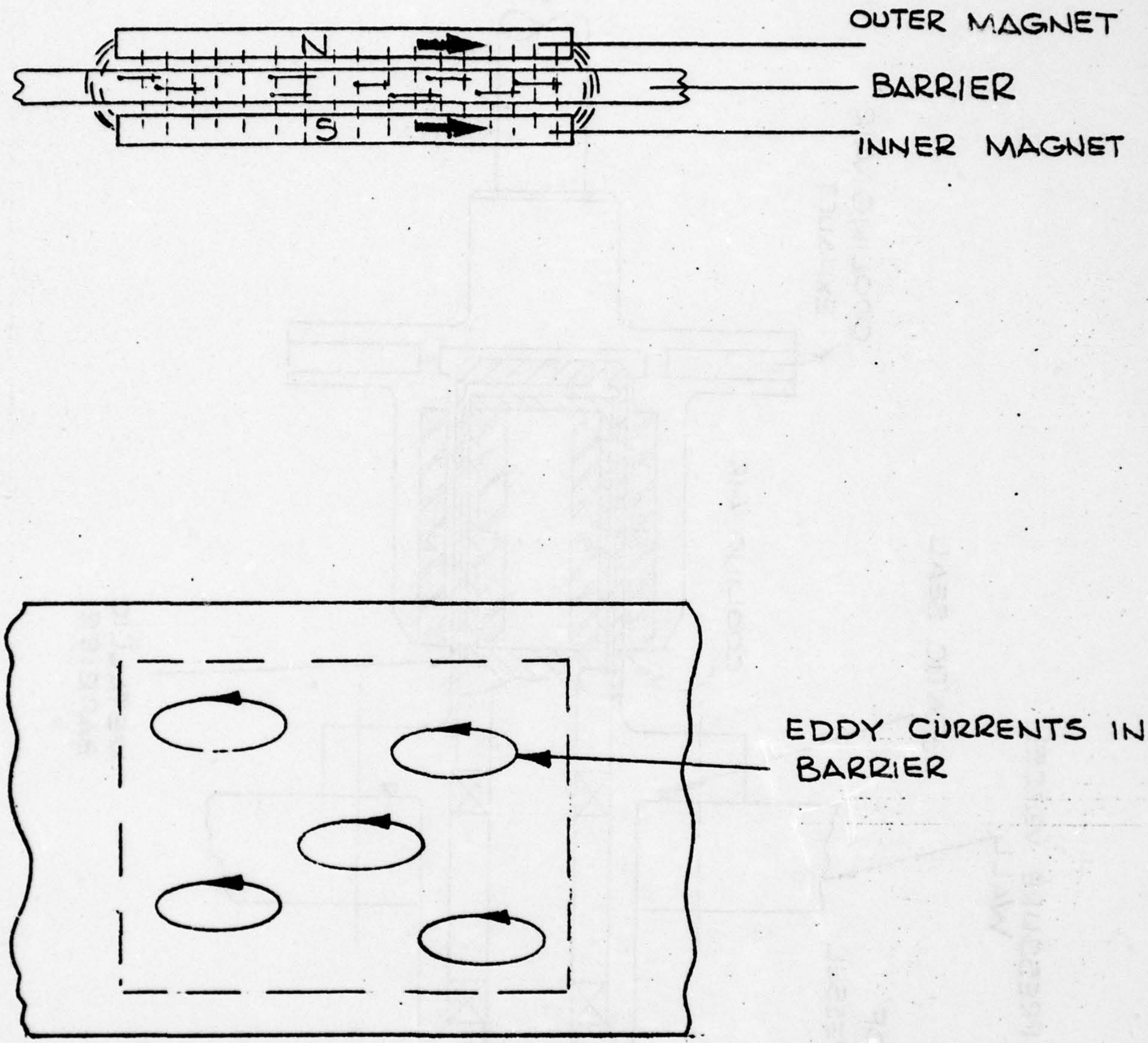


SECTION

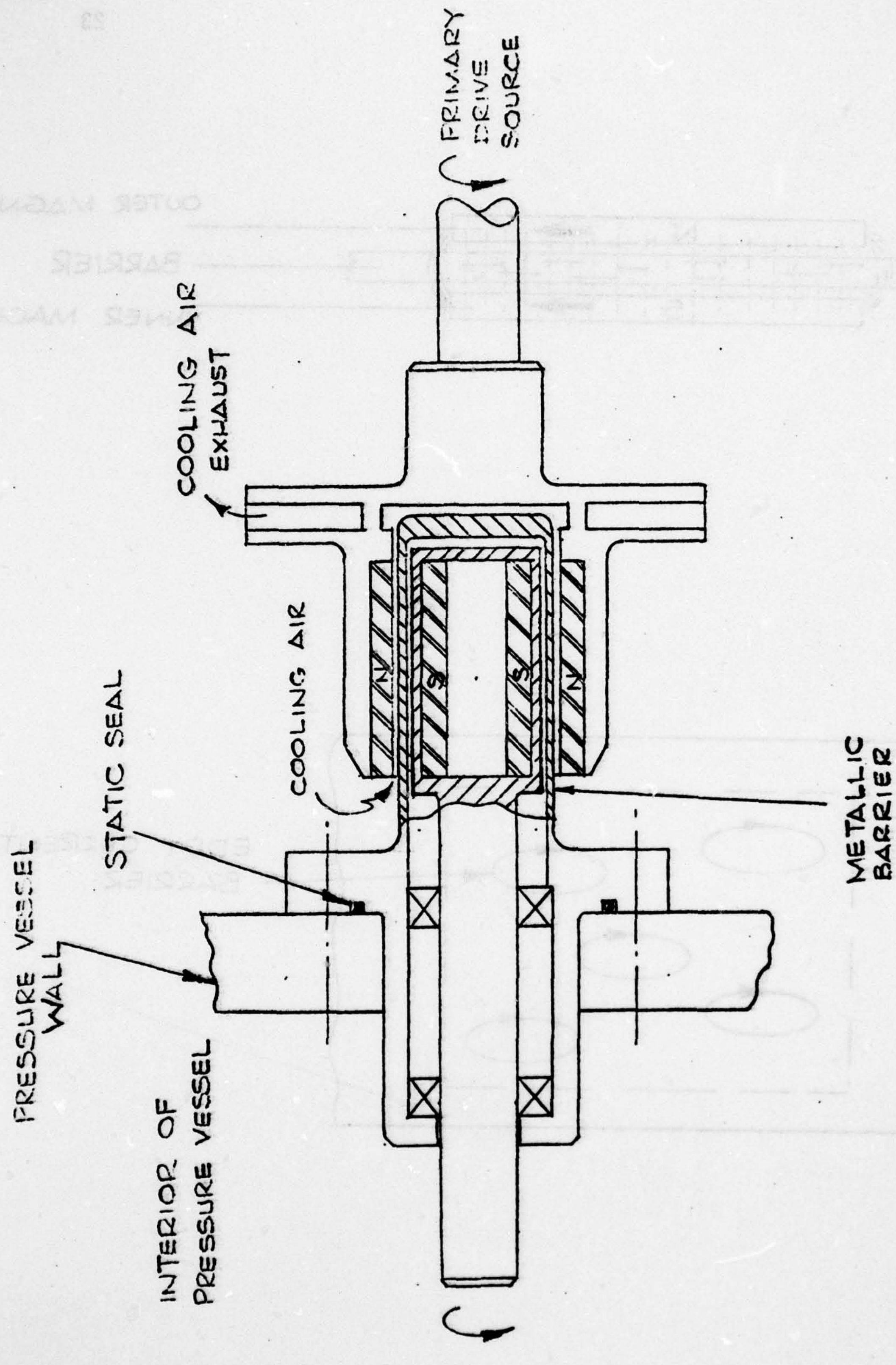


COAXIAL COUPLE

FIG. 4

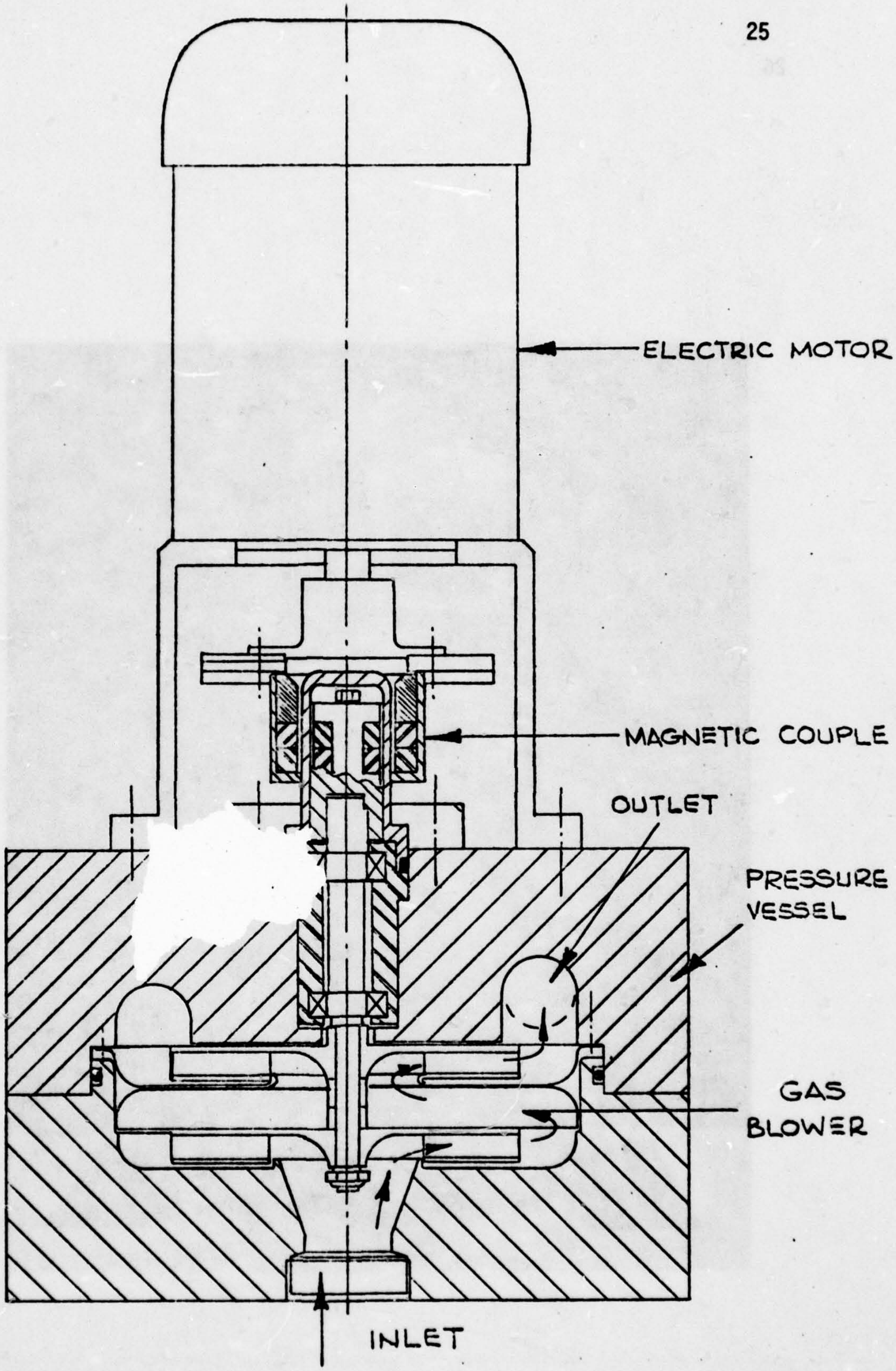


GENERATION OF EDDY CURRENTS FIG. 5



PATENTS PENDING

CONFIGURATION OF A COUPLE FIG. 6



HYPERBARIC BLOWER

FIG. 7

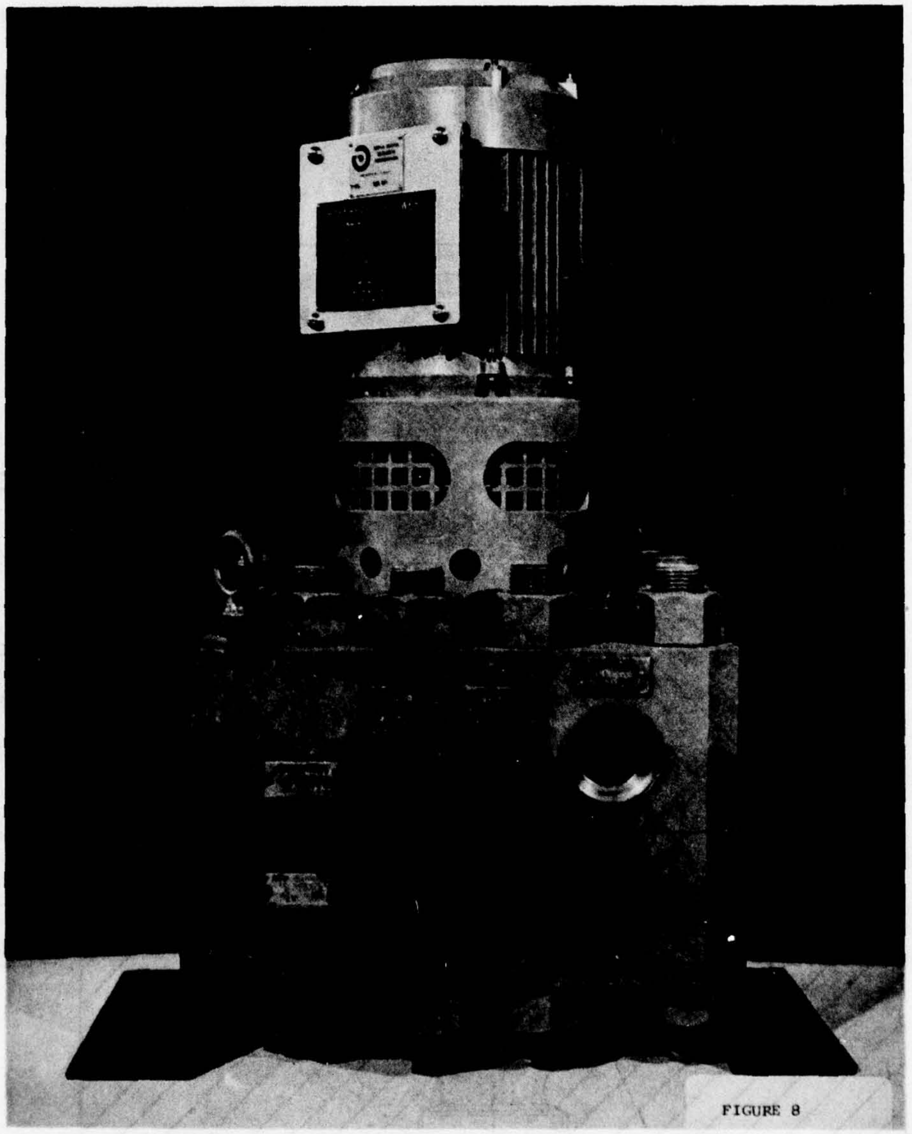


FIGURE 8

OPERATION MANTIS; DDF FIRST PRESSURIZATION

By

D.J. Fullerton, P.Eng.

Early in 1978, DCIEM was approached by Offshore Submersible Engineering Limited (OSEL) of Great Yarmouth, England to provide the services of the DDF for the Lloyds certification trials on the pressure hull of the newly developed MANTIS submersible. At the same time, OSEL wanted to conduct internal/external systems trials on the completed submersible. The DDF was selected for use because it was the closest facility which could accommodate the fully assembled system and pressurize it to the required test depth of 82.9 Bars (2700 fsw).

Prior to this, DCIEM had been tasked by the Maritime Commander to evaluate the potential of Atmospheric Diving Systems (ADS), of which, MANTIS is one, to fulfil future operational requirements in general and in particular, rescue of SDL-1 from the sea floor.

DCIEM accepted the task on condition that following the chamber trials OSEL would demonstrate the MANTIS' rescue capabilities in conjunction with the SDL-1 in Bedford Basin to aid in the completion of the ADS tasking. Both parties agreed resulting in scheduled test dates of 20 May to 3 June, 1978.

The proposed chamber dives were to include a number of pressure cycles to depths not shallower than 82.9 Bars (2700 fsw) and a manned dive to no greater than 61.4 Bars (2000 fsw) to verify the function of the internal and external systems.

To minimize the hazards due to the release of potential energy in the chamber should MANTIS incur a structural failure, it was decided to conduct the trials in a purely hydrostatic mode. Since the DDF was not designed for such tests, it was necessary to design and install a single test assembly for this purpose. Preliminary calculations indicated that pressurizing the totally flooded wet-pot to 82.9 Bars would result in a reduction of the contained water volume by nearly 34 U.S. gallons due to the compressibility of the fluid at the increased pressure. Replacement of this volume by the addition of water was necessary to maintain the hydrostatic pressure. This was successfully achieved by connecting the output piping from the Potable Water System to the wet-pot. Pressurizing the water tanks permitted the transfer of the pressure to the chamber and provided a source of high pressure water to counteract the reduction in volume due to compression. A remotely operated shut-off valve was installed for the effective isolation of the two systems, thereby trapping the hydrostatic pressure in the wet-pot.

A two wire Helle communication system was installed to provide a back-up capability in the event of a failure of the primary communication system installed in the MANTIS. Also, the submersible pilot was supplied with a portable strobe light for signalling the chamber operator as to his status should a total communications failure occur.

To supplement the MANTIS life-support system, a single CABA system was installed inside the submersible for emergency breathing should flooding occur. Calculations indicated that a major leak in the hull causing the equalization of pressure with the chamber would result in an internal submersible pressure of less than 0.5 Bars. The duration of CABA was adequate to provide a breathing source for the duration of a dive abort procedure.

The MANTIS arrived at DCIEM on Saturday, 20th May after completing a number of shallow dives in the Bay of Quinte at Canadian Forces Base Trenton. On Monday, 22nd May the submersible and its support equipment were transported to the immediate area of the DDF. Installation into the wet-pot was completed by late afternoon.

On the 23rd May full MANTIS systems checks were performed and interfacing with the DDF supporting systems was completed to the satisfaction of OSEL and DCIEM.

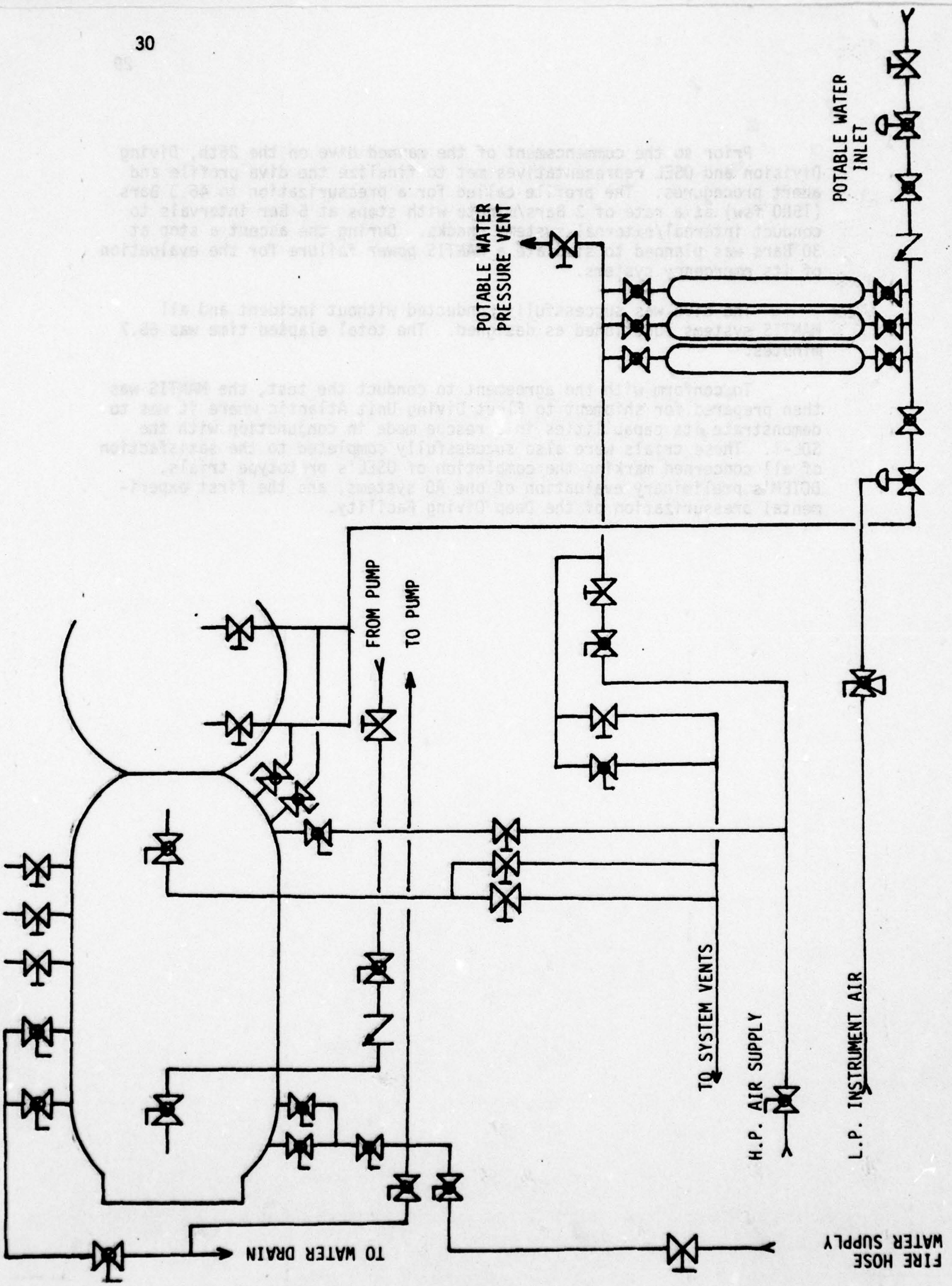
A dive to 2 Bars (66 fsw) was conducted later the same day for a period of ninety minutes. Upon completion, the pilot reported a slight leak in the area of the rear dome. Upon surfacing, the area was visually inspected in an effort to identify the source of the leak. Two further dives were attempted, however the leak persisted. Disassembly of the dome and its connecting ring revealed that the O-ring between the GRP hull and the mating ring located between it and the dome was not sealing due to dimensional incompatibility between the O-ring and its groove. Remachining of the groove the following day facilitated the fitting of a heavier O-ring thereby providing sufficient compression to effect a pressure seal.

The unmanned dive was conducted on 25th May to a maximum pressure of 92.8 Bars (3024 fsw). MANTIS was maintained at this pressure for thirty minutes followed by a controlled ascent to 3 Bars. Two further pressure cycles were conducted to this depth and held for five minutes each at the maximum pressure. Following the final cycle the chamber was brought to the surface and dewatered, thereby completing the pressure trials for Lloyds certification of the MANTIS hull. The total dive time including dewatering of the wet-pot was 279 minutes.

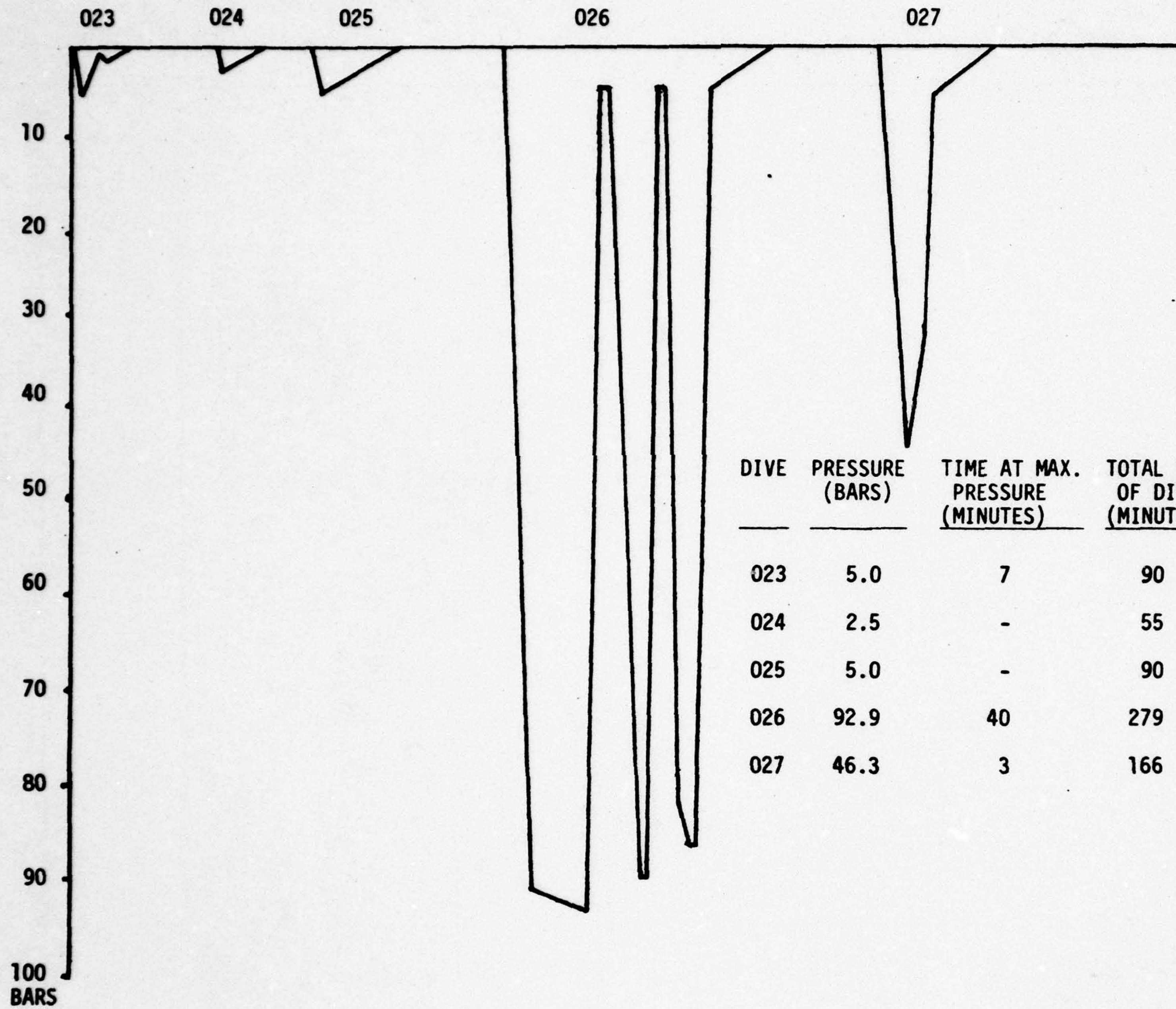
Prior to the commencement of the manned dive on the 26th, Diving Division and OSEL representatives met to finalize the dive profile and abort procedures. The profile called for a pressurization to 46.3 Bars (1500 fsw) at a rate of 3 Bars/minute with stops at 5 Bar intervals to conduct internal/external systems checks. During the ascent a stop at 30 Bars was planned to simulate a MANTIS power failure for the evaluation of its emergency systems.

The dive was successfully conducted without incident and all MANTIS systems functioned as designed. The total elapsed time was 65.7 minutes.

To conform with the agreement to conduct the test, the MANTIS was then prepared for shipment to Fleet Diving Unit Atlantic where it was to demonstrate its capabilities in a rescue mode in conjunction with the SDL-1. These trials were also successfully completed to the satisfaction of all concerned marking the completion of OSEL's prototype trials, DCIEM's preliminary evaluation of one AD systems, and the first experimental pressurization of the Deep Diving Facility.


POTABLE WATER INLET
POTABLE WATER PRESSURE VENT
FROM PUMP
TO PUMP
TO SYSTEM VENTS
H.P. AIR SUPPLY
L.P. INSTRUMENT AIR
FIRE HOSE WATER SUPPLY
TO WATER DRAIN

MANTIS TEST PROFILE



DIVE	PRESSURE (BARS)	TIME AT MAX. PRESSURE (MINUTES)	TOTAL TIME OF DIVE (MINUTES)	REMARKS
023	5.0	7	90	Manned
024	2.5	-	55	Dive Aborted
025	5.0	-	90	Dive Aborted
026	92.9	40	279	Unmanned
027	46.3	3	166	Manned

DCIEM DIVING PROGRAM GENERAL

By

LCdr B.A. Ridgewell

INTRODUCTION

This paper will provide some background on DCIEM and elaborate on the Canadian Forces Diving Research Program.

DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE (DCIEM)

The Defence and Civil Institute of Environmental Medicine (DCIEM) was created in April, 1971 with the amalgamation of the Defence Research Establishment Toronto and the Canadian Forces Institute of Environmental Medicine. DCIEM is one of six research institutes within the Department of National Defence (DND) and is located in Toronto, Canada. It is the only DND Institute that has a charter to work with other government departments, civilian organizations and Canadian industry. DCIEM is the National Institute for human research in Canada. The mission of the Institute is to improve the "Human Effectiveness of Man-Machine Systems in Hostile Environments" for the Canadian Forces.

Within DCIEM there are five research divisions, one operational training school, the Canadian Forces Central Medical Board, as well as Administrative and Technical Support Divisions. Of these divisions, a high percentage of the Biosciences Division, all of Diving Division, and about 50% of the Operational Training School is devoted to diving research and development, test and evaluation and training. These divisions do the majority of the work in the "Man Underwater" research program.

"MAN UNDERWATER PROGRAM"

The Canadian Forces have one research and development program which is associated with man-in-the-sea. This R and D program is called "MAN UNDERWATER" and is organized into the following three sub-programs:

a. Diver Systems and Techniques;

b. Submersible Systems and Techniques; and

c. Diving Biomedical Research.

These sub-programs are managed by different disciplines within DCIEM, however, all are co-ordinated, supervised or monitored by the Director of Diving Division.

DIVER SYSTEMS AND TECHNIQUES

The Diver Systems and Techniques sub-program is managed by a Clearance Diving Officer and supported primarily by military divers and technicians from the Diving Division. The emphasis in this sub-program is on test and evaluation, with some development work of diving equipment prior to approval for operational use by the Canadian Forces. At present, there are the following five projects in this sub-program:

a. CABA System Project;

b. SSBA System Project;

c. CCBA System Project;

d. Underwater Tools Project; and

e. Operational Decompression Computer Project.

CABA System Project

The Compressed Air Breathing Apparatus (CABA) project team has been responsible for the test and evaluation of single-hose regulators for the Canadian Forces. This comprehensive evaluation has resulted in the selection of a single hose regulator which is presently under procurement and which ultimately will replace our existing double-hose regulators. A secondary task of this team has been to investigate the interfacing of the DCIEM (*Kuehn/Pogarski*) passive heat reclaimer in the mouthpiece of the new single-hose regulator. Another task has been to develop a medium pressure and ultimately a high pressure gas stowage reservoir which utilizes H.P. tubing.

SSBA System Project

The Surface Supported Breathing Apparatus (SSBA) project team has been responsible for testing and evaluating various umbilical supplied hard hat diving systems. This work has resulted in the selection of the Oceaneering International "Rat-Hat" for the Canadian Forces. A new neoprene dry suit to interface with this helmet has been developed by DCIEM in co-operation with a Canadian diving suit manufacturer. Umbilical hoses and communications cables from Pneu-Hydraulics Ltd., U.K. have been selected. This complete new SSBA system is in the procurement stage and delivery to the operational units is expected early next year.

CCBA System Project

The Closed Circuit Breathing Apparatus (CCBA) project team have been tasked by our headquarters to find a replacement for the CDBA by 1982. A market survey of suitable diving systems is to be completed by the end of this month. This team will be evaluating the USN non-magnetic version of the "Biomarine CCR1000", the French Navy's "DOXGERS" and a

recently developed Swedish diving set. Depending on the results of our survey, DCIEM is prepared to develop our own set if there is sufficient justification to do so.

Underwater Tools Project

A small project team is evaluating various underwater tools. The Canadian Forces recently purchased new hydraulically operated tool kits from the USN. These kits are now operational in our Fleet Diving Units. Our future area of interest is in the diver operated hull cleaning equipment.

Operational Decompression Computer Project

DCIEM's primary diving research project in the last few years has been with decompression computers. The major advance in decompression computers has been the switch from pneumatic analogue computers to all electronic digital computers. These computers have been tested, modified, retested to the point where we are now happy to evaluate them under operational conditions. It is intended to run an extensive series of dives utilizing DCIEM's new Deep Diving Facility with 10 divers, various water temperatures and various workloads to determine the decompression computers safe operational envelope.

SUBMERSIBLE SYSTEMS AND TECHNIQUES

The Submersible Systems and Techniques sub-program is new and has been fostered by recent developments in submersibles, Atmospheric Diving Systems (ADS) and Remote Controlled Vehicles (RCV). This sub-program is managed by the hyperbarics facilities engineer and is supported by a small team from the Diving Division. The purpose of this program is:

a. to evaluate AD Systems available to DND;

b. to conduct manipulator R and D; and

c. to investigate RCV Systems.

AD Systems

DCIEM would like the opportunity to evaluate JIM and WASP ADS, however, at present these systems are not available to us; consequently, we are closely monitoring RN and USN evaluations of JIM. DCIEM conducted a preliminary evaluation of the MANTIS ADS in June of this year. Three unmanned dives to 92 Bars (3000 fsw) and a manned dive to 46 Bars (1500 fsw) were successfully completed at DCIEM using the DDF wet chamber. MANTIS completed 24 dives in Halifax, Nova Scotia and demonstrated her mobility and dexterity by connecting a lifting line to the sail of the SDL-1 submersible thereby simulating a rescue of a damaged submersible. The MANTIS ADS concept has considerable potential as a seabed work vehicle, consequently, as a result of this preliminary evaluation, DCIEM is purchasing MANTIS X4 from OSEL, Great Yarmouth, U.K. to conduct further evaluations.

Manipulator R and D

The major weakness of submersibles and AD Systems is the limited dexterity of the manipulators on these vehicles. For this reason, DCIEM will commence research and development of force feedback manipulators in the new year.

RCV

Remote Control Vehicles and Systems will be investigated in the near future to determine their possible use to the Canadian Forces. There can be no doubt that they have considerable potential in mine counter measures.

DIVING BIOMEDICAL RESEARCH

The Diving Biomedical Research sub-program is managed by Dr. Kuehn of the Biosciences Division. The major areas of DCIEM diving research are:

a. thermal protection;

b. compression - decompression;

c. neurological disorders; and

d. diver selection performance.

Thermal Protection

It is the belief in DCIEM that thermal protection is the major problem limiting diver performance at all operational cold water depths from the shallow to the very deep. With the exception of surface-supplied hot water suits, all divers wearing conventional diver clothing eventually become hypothermic, if immersed long enough. A thermal heat flow monitoring system has been developed by DCIEM which measures a diver's temperature, heat loss and clothing and physiological insulation. It has been used to document diver thermal stress in many cold water environments, from open-water working dives to very deep saturation experiments and has been instrumental in the development of several passive heating concepts which show promise of alleviating the degree of stress. A diver operational physiological monitor has also been produced as a result of this research.

Compression - Decompression

DCIEM has been in the forefront of decompression computer research for the last 15 years, an endeavour that has resulted in development of several generations and types of decompression computers and calculators, some of which, are now commercially available. The XDC-1 decompression calculator is a table-top digital microprocessor-based system that can be

used in real-time to monitor actual diving or in accelerated-time for the planning and study of dive possibilities. It is inherently a laboratory tool. The XDC-2 decompression computer is a real-time decompression monitor for operational or field diving. It is presently used in the Canadian Forces Fleet Diving Units for hyperbaric chamber operations and surface/umbilical supported operational diving. A recent development has been the XDC-3 sports diver decompression computer which will be internationally marketed by next summer. Finally, the latest in this computer series is the XDC-4 Decompression Management System intended for operations with the DDF. It is a versatile microprocessor system that permits real-time monitoring of hyperbaric experiments in conjunction with several mathematical modelling analyses of the decompression process involved; ideally it will serve as a tool to development of even more sophisticated decompression computers in the future, particularly those involving gas switching.

Neurological Disorders

Considerable research is being conducted at DCIEM into the effects of rapid decompression from simulated deep depths on the inner ear systems of laboratory animals. Lesions and occluding bone growths have been observed in inner ears of severely-decompressed squirrel monkeys, which have further resulted in physiological events similar to those experienced by divers suffering from neurological or Type II decompression sickness. It is hoped that understanding of the laboratory cases will aid in the understanding and prevention of such occurrences in operational divers. The high pressure nervous syndrome (HPNS) problem associated with deep rapid compression is also under investigation at DCIEM through contractual university research.

Diver Selection and Performance

A psychological screening profile for detecting potential divers is under development at DCIEM. Early application of a preliminary profile has met with some success and work will be continued to obtain a simple protocol for the selection of ship's divers initially and eventually Clearance and Saturation Divers. Various psychomotor tests are also under development to determine the effects of various parameters of the hyperbaric experience on diver performance.

CONCLUSIONS

The "Man Underwater Program" is an ambitious research program which is being expanded in scope at DCIEM. We are fortunate in having some of the finest hyperbaric facilities in the world, however, our greatest asset at DCIEM is the close-working relationship which exists between our multi-disciplined personnel. The formation of project teams which span the scientific, engineering, medical and operational personnel has been the secret of our success to date and will continue to be in future. We intend to make significant contributions to solving the problems associated with placing working divers on the seabed.

REGULATIONS RESPECTING DIVING OPERATIONS IN SUPPORT OF OFFSHORE MINERAL RESOURCE ACTIVITY

By

Mr. D.G. Hunt

Department of Energy, Mines and Resources

The Department of Energy, Mines and Resources, through its Resource Management and Conservation Branch, is responsible for the regulation, supervision and control of activities involving the exploration for and the exploitation of mineral resources off the east and west coasts of Canada and in the Hudson Bay and Hudson Strait regions. An equivalent branch of the Department of Indian and Northern Affairs carries out the mineral resource administration in the remaining areas of Canada Lands, the administrative boundary in the Labrador Offshore being approximately 61°18'N latitude.

Authority for control of offshore mineral resource activities is provided by Parliament, primarily by means of the Oil and Gas Production and Conservation Act. Our objectives at Resource Management and Conservation Branch are to ensure the safety of persons taking part in exploratory or development operations, to protect the environment and to prevent the waste of resources. Basically, we do this by promulgating and enforcing regulations, by evaluating programs for suitability of methods and equipment prior to the commencement of operations, and by inspecting, on site, the operations to ensure compliance with regulations and the submitted program and to ensure that conditions are as predicted. The right to make regulations and to inspect sites are spelled out in the act, as is the right to shut down an operation which is unsatisfactory.

Exploratory drilling for oil and gas began in areas under EMR jurisdiction in 1966 and to date, some 150 wells have been drilled. A total of 22 different drilling rigs have carried out programs in water depths ranging from zero to 900 meters. The types of drilling units varied from dynamically-positioned drillships to a rig mounted on a fixed platform and included at least one of every major type of offshore unit in use today, including anchored drillships, anchored barges (semi-submersibles), a semi-submersible operating in the submersible mode (sitting on bottom) and a self-elevating (jack-up) rig.

Although the record of discoveries of oil and gas has not been as spectacular as in some areas of the world, the quality of the operations has been of a high standard. There have not been any incidents causing serious pollution, nor have there been any cases of waste of resources. Unfortunately, however, there have been five fatalities associated with the offshore drilling effort. Four of those deaths were divers engaged in diving operations.

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Diving tasks associated with offshore operations fall into many and varied categories. Anything from humping sand bags in 13 meters of water to jury-rigging auxiliary hydraulic controls 313 meters deep. In general, the drilling equipment used in offshore operations is designed for remote control operation (so-called "diverless" systems). Divers are needed, however, when malfunctions occur.

The number of hours actually spent diving is relatively small. An average per drilling rig of two, two-hour dives per week involving two divers would not be far off. This amounts to eight diving manhours per week per rig. The average time required to complete a well is around 12 weeks, so that you could say that each well involves about 96 to 100 manhours of diving. For all of the wells drilled so far, there would not likely be more than 15,000 manhours of underwater time.

This leads to the conclusion that so far, there have been four diving fatalities in 15,000 hours on the job, or 1 for every 3,750 manhours. If the same casualty rate applied to the total work-force of this country, then you could expect 20,000 on-the-job fatalities per day and your average career expectancy (not counting retirement) would be a bit less than two years.

It is obvious that these statistics are a severe exaggeration caused by extrapolating from a very small data-base to a very large one. However, it is only common sense to expect the number of accidents to increase as the amount of diving activity escalates. This is exactly the way it occurred in the North Sea as oil and gas development projects were undertaken and the usage of divers increased dramatically, so did the casualty count.

The British and Norwegians responded to this problem by instituting regulations on training, equipment and operations and by close inspection of diving facilities and activities to ensure that these regulations are strictly adhered to. We at RMCB are in the process of implementing similar procedures. We hope to have the regulatory and control procedures well in hand before oil and gas development begins and brings with it a tremendous increase in diving activity.

The first step in establishing Canadian Offshore Diving regulations was to identify what diving expertise was available within Government and outside Government in the form of consultant services. This led us to association with people at DCIEM and the Armed Forces.

Next, representatives of RMCB and DCIEM travelled to Europe to meet with the diving authorities of the North Sea countries to obtain their ideas on the regulations of the diving industry and the operations aspects of enforcing the regulations. They also had the opportunity to discuss with leading diving contractors the direction of research in diving and the probable impact of the government regulations on present and future activities.

Diving operations have been subject at RMCB inspection since the commencement of exploration, but with a view to imposing more stringent requirements once the regulations were developed and in place, and because of the limited expertise available on staff, we engaged a consultant to check out the diving equipment aboard each offshore drilling unit that was operative in our areas in 1978.

We simultaneously undertook with the assistance of DCIEM, to conduct a review and comparison of available diving regulations from all over the world.

Next we wrote a draft set of regulations based on what is common practice in areas similar to the Canadian offshore in environment and type of operations. We also took into consideration, those aspects of diving activities which are unique to the Canadian offshore.

In the very near future, we will be providing copies of the draft regulations to the Canadian diving industry for review and comment. We will request that as far as possible comments be incorporated into one reply for each group involved in diving operations. To this end, I would be interested to know of any divers' associations in the marine area of Canada. We will subsequently arrange to meet for a discussion of the points brought up in the written comments. This is the procedure which we followed for the drafting of the Canadian Oil and Gas Drilling Regulations and we found that it worked very well.

Once general agreement is reached on the technical content of the diving regulations, all that remains is to have the legality of the language reviewed by our lawyers. The regulations can then be made law by an Order in Council.

In closing, let me repeat the view of RMCB, that there is definitely a need for greater safety in diving operations associated with offshore oil and gas activities, and that our approach to this need is to draft regulations. It is to the benefit of all those contractors who have been or intend to be employed in this area to assist in establishing a reasonable set of regulations, as they are the people who will live with them.

DIVE MONITORING EQUIPMENT - SUPERVISION AND RECORDING

By

L.J. Retallack, Ph.D.

CTF Systems Inc.

ABSTRACT

Two functions of importance stand out with respect to computer applications in the diving field. The first is calculation and display of diver status - current depth, tissue gas loadings, time to surface etc. - providing information used to control the progress of the dive; the second is the permanent recording of the above data for future analysis. CTF Systems Inc. began with the first function with the XDC-1, XDC-2 and XDC-3 digital decompression monitors, combined both functions in the XDC-4 Deep Dive Management System, and has now augmented the XDC-2 operational instrument with the directly compatible DDL-1 Digital Data Logger. The supervisory functions of the XDC series are sufficiently well known that only brief mention is made of them; data recording concepts used in the XDC-4 floppy disc recording and the DDL-1 digital cassette recording are discussed in detail with particular emphasis on user interaction and control over data format.

INTRODUCTION

In conjunction with DCIEM, CTF Systems Inc. has developed a series of dive supervision instruments of varying levels of complexity. The family of four decompression computers began with the XDC-1, a desk-top calculator used for analyzing and planning dives and for real time supervision of actual dives. The packaging is not very robust, and being line operated only the unit is unsuitable for use in harsh or electrically uncertain environments.

The XDC-2 is aimed more at field applications. It is packaged in a cast aluminum case with splash proof front panel, and can be operated from line power, 12 volt external battery, or in an emergency, on internal rechargeable batteries. The calculator mode of the XDC-1 has been deleted and the unit is aimed purely at supervisory applications; the XDC-2 includes a high quality pressure transducer.

The XDC-3 is a diver portable version of the XDC-2, re-packaged in a pressure proof aluminum box designed to be strapped to a SCUBA tank. A rubber hose leads from the unit to a cylindrical console containing the LED displays and an inertial switch which activates them for a few seconds when the console is shaken. The last feature saves battery power by

leaving the displays turned off unless they are needed. Power is supplied by four nine volt batteries. Like the XDC-2, the XDC-3 is strictly a real time monitor and contains a pressure transducer.

The last member of the family is the XDC-4 Deep Dive Management System. It comprises three distinct micro-computers dedicated to Real Time Monitoring, Development, and Input/Output functions. A high speed, fully programmable 48 bit bit-slice arithmetic processor handles mathematical operations for all three computers and mediates inter-processor communication.

User interaction is effected through the Development System via a storage tube display terminal. Bulk storage consists of a dual eight inch floppy disc system also accessed by the Development System; Disc I is used for storage of system software and user operated program workspaces, Disc II is reserved for a data logging function.

The I/O processor comprises two serial digital input/output ports, four analog outputs, plus eight differential or 16 ground referenced analog inputs. The six output channels can be used for data display and recording as described in a later section.

DIGITAL DATA LOGGER

Basic Concepts

To augment the monitor function of the XDC-2, a Digital Data Logger - DDL-1 has been developed by CTF Systems to record serial digital data. The unit comprises a commercially manufactured digital cassette recorder with parallel interface, four serial data input/output ports with programmable bit rates, 2048 words of read only program memory, and 2048 words of buffer storage random access memory. A hexadecimal keyboard is used for user control over the unit, determining the way in which the micro-processor controller reads, writes, and records data. Eight front panel LED's indicate the status of the unit, with eight, seven segment digits providing more detailed information as well as an immediate display of keyboard entries.

The DDL-1 utilizes the same packaging as the XDC-2 with a slightly extended box planned for the future to allow insertion of the emergency batteries. All circuits reside on five printed circuit cards which are interconnected via CTF's series 200 bus of 120 lines. A standard mother board provides bus interconnections as well as +5, -5 and -12 volt power supplies. The entire chassis can be slid forward out of the box for easy trouble shooting and maintenance.

The current version of the DDL-1 is aimed directly at recording XDC-2 output with data organized in 43 character records in the following format:

(CR) (LF) D1 D2 D3 D4 D5 D6 D7

where D1 - five characters for elapsed time

D2 - five characters for depth

D3 - five characters for ascent/descent rate

D4 - five characters for safe depth

D5 - five characters for ascent time or no decompression time

D6 - five characters representing status of the XDC-2

D7 - four characters providing the software version and serial numbers for the XDC-2

(CR) - carriage return

(LF) - line feed

Spaces follow each entry.

The records are read from the serial ports and stored in buffers dedicated to each input channel. When a buffer area is "full" i.e. three records are stored, the block is written on the tape with a header comprising (CR) (LF) (LF) block number, port number, XDC-2 status, time of day clock, the four records (or a comment) and a check sum. (The four data channels operate independently, i.e. blocks from each are not necessarily written onto the tape at the same rate but rather are dependent upon the rate of output of the corresponding XDC-2).

With four XDC-2's running at the normal rate, a single cassette will run for approximately six hours. A calculation routine keeps track of recent tape usage and projects forward an estimate of actual remaining time. When less than one hour is projected for the tape life, an LED on the front panel is illuminated and the buzzer sounds indicating that the tape should be changed. The user then has one hour to press the "D" key on the front panel, at which time the write operation is completed for the current block, and ensuing data is stored in overflow areas associated with each of the four data buffers. A tape terminate record is written to close the tape at which time the "Change Tape" LED is illuminated; the operator then has 50 seconds to remove the old cassette, insert a new one, and push "C" to continue.

If the inserted tape is neither hardware nor software write protected (if it is, the "Error" LED and buzzer both come on) the recording process continues, starting with a new tape header, then proceeding with the blocks stored during the cassette changeover. If the changeover is slow enough that the overflow buffer space is overrun, the "Data Lost" LED is illuminated and kept on during the remainder of the recording time.

The tape header comprises carriage return - line feed followed by a write protect status word which software protects a cassette previously used for recording dive data. The date, time of day clock, data logger serial number, comments and a checksum complete the start of tape information. The end of tape record starts with carriage return and two line feeds followed by an end of tape code, the date, time of day clock, data logger serial number and current DDL-1 status.

Four status lights indicate data input for each of the data channels; two others indicate "Playback" or "Record" mode and provide a power-on indicator.

DDL-1 User Control

Via the keyboard, the operator can perform a large number of control functions, a few of which are delineated in Table I. The general format is a two digit entry followed by "*" or transfer to encode the two digits as an operator followed by an operand of up to six digits. "#" or enter executes the operator-operand pair.

During recording, up to six digits may be written directly onto the tape using a keyboard entry followed by "#", to provide a simple comment capability.

Operator	Operand	Function
ØØ	hh mm ss	Enter time of day clock
Ø1	dd mm yy	Enter date
--	XXXXXX	Coded Comment
1Ø		Print all Channels
1Ø	XX	Print one Channel
99		Erase

Special Keys

Record:

A, B	Not used
C	Continue
D	Halt
*	Transfer
#	Enter or Execute

Playback:

A	Forward
B	Back
C	Continue
D	Halt
*, #	As above.

TABLE I: FUNCTIONS OF DDL-1 KEYBOARD

XDC-4 DATA LOGGING

Data logging is felt to be a prime function of the Deep Dive Management System and as such one of the two floppy discs has been dedicated to recording parameters of an ongoing dive. As with all XDC-4 disc operations, data is recorded in fields of 4096 twelve bit words, normally referred to as workspaces, and assigned five or six character alphanumeric names, e.g. DATA1, DATA2, DATA99, etc.

System operators are available for organization of the disc data logging function for the XDC-4, the execution of which can be implemented via keyboard control or within the structure of an overall dive monitor program. Insertion of appropriate comments within the data field is also possible.

The data of interest is stored within the Random Access Memory of the Fast Processor as a 64 by 16 matrix of 48 bit words. (Quadruple precision with respect to the three microcomputers).

Three sets of data are stored: one for the real time monitor of an ongoing dive, one for bail out algorithm calculation, and the third for development purposes. Currently, only 300 of the potential 1048 48 hit words are used leaving 3000, 12 bit words available for comment storage. The commands used for data logging are of the form:

DLOG2 DATA1 RDRTM

Interpreting the above line from right to left, we have the system defined operator RDRTM which copies the real time monitor dive data into the spare data field of the development processor. <DATA1> is entered into the stack as a name; DLOG2 writes the spare data field onto the second disc with the name DATA1. To insert comments the following instruction would be inserted between <DATA1> and DATRTM:

COM "DATA RECORD ON DIVE DCIEM43A, NOV 22, 1979; DIVER 1

EXPERIENCING NAUSEA, RECOMPRESSING".

The above would record the literal string on the disc in eight bit ASCII, using approximately 100 of the remaining 3000 words.

To recover data from the disc, a command of the form WRDEV RDLOG2 DATA1 would pull DATA1 into the extra data field; then write it into the matrix area reserved for the development system. From this point, the data could be used to complete a simulated dive from the given point in the actual dive, or compared with other sets of data, or printed out on hard copy for analysis.

Use of the input/output processor provides another vehicle for recording data in a permanent form. Either or both of the digital ports can be used to output data at a switch selectable baud rate between 110 and 9600 band. Data to be output can be selected by defining a user program based on the operators DI01, DI02 which output a selected variable or variables on either RS232 port.

Similarly, the four analog output channels can be used to output desired variables using the commands A01, A02, A03, A04. Scaling is possible using standard arithmetic operations.

As with other aspects of the XDC-4, the functions performed are limited only by the ingenuity of the programmer; all necessary basic functions are provided within the Dive Control Language.

CONCLUSIONS

By providing data logging capabilities in conjunction with dive supervision by XDC-2 and XDC-4 dive management equipment, comprehensive dive monitoring systems are now available. The DDL-1 is dedicated currently to the XDC-2 but future software development of a quite minor nature could expand the functional utility to include a broad array of serial digital outputs. The XDC-4 provides a flexible vehicle for data recording either on the second floppy disc as a matrix array of dive parameters or in a user specified format via one of the two digital serial of four analog outputs. CTF Systems Inc. looks forward with great interest to future developments in the recording and display of diving data.

INDUSTRY, TRADE AND COMMERCE AND UNDERWATER CANADA

By

Mr. R.F. Fortier

Department of Industry, Trade and Commerce

An initial overview of the Ocean Industries in Canada was provided with a definition of the objectives of the Department of Industry, Trade and Commerce and our Ocean Industries Division. Reference was made to "A Report by the Sector Task Force on the Canadian Ocean Industry" which was one of 23 reports prepared by the Department of I.T.&.C. on Canadian industry sectors. This included a discussion of the sector profile giving details of the ocean industry sector, reasons for the setting-up of the task force, and planned follow-up of the study. The report is available for distribution to all interested parties.

An update was given on the Underwater Study initiated by Larry Edelstein, previously of the Ocean Industry Division. The modified terms of reference were discussed and the objectives and evaluation of the study were outlined. The results expected were also discussed and noted that participation of all associated industries in underwater activities in Canada was essential to achieve useful conclusions in this report and ensure its usefulness to Canadian industry.

Highlights of some developments were also discussed covering Dome Petroleum's drilling program in the Beaufort Sea; Horton Maritime Explorations Ltd., Submarine Piccard, presently on route to the Gulf of Mexico; Hunctec '70 Ltd., Deep Towed System Program; Hermes Data Buoys; Fathom's Fairings. These were a few specific examples of some of the highlights of the recent developments within our Canadian Ocean Industry.

Problem areas were also discussed covering such areas as International Hydrodynamics Company and Undersea Equipment Ltd. The points were raised that co-operation between the smaller industries in Canada is essential if a more stable base of ocean industries is to be achieved.

The future of the ocean industries was also discussed. This referred to the Ocean Industries Division analysis of related business information including markets, R&D, financing, etc. and efforts to assist in consolidation of activities for the benefit of related industries.

The potential of increased drilling off Labrador in Newfoundland area and the forecasted increased activities by Dome in the Beaufort Sea was discussed. The Federal Government has recently indicated its strong support in this area of ocean industries which is one of the few potential growth areas within our Canadian industry sector.

POLICE DIVING

By

Constable R.W. Hancock

Ontario Provincial Police

The Province of Ontario is divided into 17 Districts by the Ontario Provincial Police. Each district is headed by a District Dive Master and he usually has two other Force divers who work with him within that District. Some busier Districts may have up to seven divers, while less active Districts may only have two. The allotment of divers for the province is set at fifty-one. A Senior Force Diver is appointed to head the diving within the province and the District Dive Masters are responsible to him. If a big or particularly long diving operation occurs, then the Dive Master from one District may call upon the service of a Dive Team from another District.

The ultimate head of diving operations within the province is the Assistant Commissioner, Field Division. The Senior Force Diver is directly responsible to him. Under the Senior Force Diver, we have the 17 District Dive Masters. These Dive Masters are responsible to the Senior Force Diver, the respective Superintendents of their Districts and the Detachment Commanders of whatever Detachment area they may be diving in. Under the District Dive Masters, we have the body of our diving team, the Force Diver. The Force Diver is responsible to his District Dive Master and has an operational choice. By that we mean, he has the opportunity to refuse a dive if he feels he cannot safely do so for whatever reason--whether he has a head cold or sinus problems. In the event of an emergency, the whole chain of command is by-passed and the accident victim is transported immediately for treatment.

Our divers are issued all of their equipment by the Force. They are called out by our investigators for a variety of reasons and must be ready at any time to dive under varied conditions.

Unlike the sport diver who chooses his dive sites and days carefully, an Ontario Provincial Police Force Diver must dive in fast-flowing rivers with poor visibility or under the ice.

The "Buddy System" is strictly adhered to at all times and when ice diving, a third diver is fully suited and remains at the surface to act as a safety diver should the need arise.

We are called upon to recover vehicles from the water whether they are stolen cars which are run into the water to avoid recovery or a car which has ended up in the water as a result of an accident. To enable us to recover and raise these submerged vehicles, proper salvage methods are practiced at our annual requalification courses.

Our divers assist our criminal investigators in a variety of ways; one of which is the recovery of murder weapons, or weapons used in the commission of a crime. Through the use of our underwater metal detectors, even tiny objects such as spent shell casings may be retrieved from the water.

Another aspect of police diving is the recovery of stolen property, as depicted in these slides by the divers recovering a stolen safe.

We are also called upon to work on major marine and aviation disasters. This slide is a picture of the superstructure of the "EAST-CLIFF HALL". This ship ran aground and then sank in the St. Lawrence River. Eight divers worked for seven days to recover the eleven bodies which were trapped inside this ship when it sank.

This vessel, a fishing tug called the "Verna Jane", ran into a sheer rock cliff during a fierce storm on Lake Superior. The boat sank immediately, coming to rest at the base of a cliff in 110 feet of water.

You can see how the cabin exploded off the vessel as she sank to the bottom. Three men lost their lives in this accident. Ontario Provincial Police divers recovered two of the victims inside the tug; however, the third victim was never located.

Courses have been conducted by the military to instruct our men and assist them in the recognition of underwater explosives.

In the Sudbury area in 1977, a large cache of old dynamite was found on the bottom of a remote lake. Our job was to gather up all this dynamite and take it to shore where it could be disposed of by our Identification personnel who are fully trained in such matters. This task, which was simplified by the clear water and shallow depths, was, nonetheless, dangerous because of the unstable condition of the old dynamite. Before the job was completed, 20 cases of the explosives were located and retrieved. Each case contained 125 sticks of dynamite.

Security checks on areas where V.I.P.'s will be attending are an important aspect of police diving. In this slide, our divers are preparing to check the area known as Ontario Place. In this instance, these checks were being made in preparation for the visit of our Queen to Ontario Place. All the "pods", docks, bridges, walkways, etc. had to be checked one hour prior to the arrival of any visiting dignitaries.

The majority of police diving, approximately 95%, involves the recovery of drowning victims.

Diving at night is not normally done by our divers. An exception to this rule would be if a car or airplane crashed into a lake or river and there was some chance that survivors might be alive and breathing air trapped inside the wreckage. Normally, though, we would organize our men and be ready first thing in the morning to begin to dive.

Force policy restricts us to dive at depths not exceeding 100 feet. This slide shows a police diver ready to make such a deep dive.

This slide, unfortunately, has nothing to do with police diving. I merely put it into this presentation to see how many of you are still paying attention.

The circumstances dictate how a given area will be searched; however, we find that the majority of our searches are conducted on sleds.

The search area is marked using buoys such as "Javex" bottles and the divers are towed behind a skiff at a slow speed. The boat operators maintain the pattern and the divers act as a pair of eyeballs on the bottom. A signal line can be attached to the sled and the diver, using a set of signals to his tender, can instruct the boat operator to tow him at the proper speed keeping in mind the bottom conditions and visibility. In this manner, a very large area can be effectively searched with little effort to the diver.

In the spring of each year, a course is held for our Force divers to update their knowledge in diving. This course is held in conjunction with our marine section and their members are taught how to work with divers.

The Ontario Provincial Police has a marine complement of sixty-two inboard-outboard skiffs, up to 21 feet in length and thirteen launches over 30 feet long. These vessels are strategically placed thoughout the province on its various inland lakes and rivers.

On occasion, it is necessary to fly into a remote area to work on a diving detail. In the past, we have had to rely on the Ministry of Natural Resources for their aircraft. With air travel becoming more necessary, the Ontario Provincial Police purchased two Turbo-Beaver aircraft and stationed them at Sioux Lookout and Timmins. We also have purchased two Jet Ranger helicopters. Both of these helicopters are posted to General Headquarters here in Toronto.

Often, the marine crew and the air crew are called upon to work together to assist our divers on an operation.

In addition to transporting our divers and their equipment, the helicopter is a useful tool in that a diver may be lowered into or picked out of the water in an area that is unsuitable for landing.

Annually, in the spring, our Force divers meet at conference centres like this one in Orillia for a refresher course. At these courses they are retested on their basic life-support skills, and brought up-to-date with new information which is obtained through the experts here at D.C.I.E.M. In addition to the classroom lecturing, the members have two full days of open-water diving. During this week, an overall evaluation is made of each man and they are either requalified as a Force Diver for another year, or removed from the team.

In June of 1975, eleven R.C.M.P. diving instructors were trained by experts at D.C.I.E.M. and the Senior Force Diver of the Ontario Provincial Police. This course united police divers across Canada and established equal diving and training standards for them. In addition to this, recently at the University of Michigan, in Marquette, one R.C.M.P. instructor from British Columbia and the Ontario Provincial Police Senior Force Diver, repeated a similar course where forty police diving instructors from most of the states of the United States received the same techniques and material to amalgamate Police Diving in North America.

One final aspect of Police Diving in Canada is the investigation of all diving accidents. In Ontario, our District Dive Masters investigate these accidents and through their findings, and the findings of the experts at D.C.I.E.M., regarding air analysis and equipment testing, a conclusion is reached as to the cause of the accident.

INNOVATION IN UNDERWATER ILLUMINATION:

THE BALLASTLESS GAS DISCHARGE LIGHT

By

Mr. R. Fraser

MSE Engineering Systems Limited

ABSTRACT

Previously, there have been two basic types of underwater illumination systems--incandescent and gas discharge, each with its own advantages and disadvantages. Recently, a light has been developed which maximizes the advantages of both types, while minimizing the disadvantages of each. This light is the ballastless gas discharge lamp that combines a tungsten heating filament and a gas discharge element within the same pressure envelope. This paper details the operation of the lamp and discusses its application for offshore work.

The practical improvements that the ballastless gas discharge light allows are numerous. Mercury vapour or thallium iodide gas discharge lights generate a spectral output in the blue-green region which is well-suited to the attenuation characteristics of water. Thus for optimum penetration under water, gas discharge lights are used. However, such lights require a separate, expensive ballast and a warm-up period before light is produced. Since the incandescent element acts as a starting resistor in the ballastless light, the requirement for a ballast to generate a high striking voltage is eliminated. Similarly, current regulation during operation is no longer necessary. The incandescent filament also allows light to be generated immediately--without a warming up period.

Applications will remain where the conventional gas discharge or incandescent lights are preferable. However, the ballastless gas discharge light represents a real innovation in underwater illumination. Never before have the two types of lights been combined in one envelope designed for underwater use.

INTRODUCTION

The study and exploration of the worlds oceans and lakes is an ever-expanding challenge. The gathering of visual data, using photography and underwater television, has become one of the primary means of studying this underwater environment. Except in very shallow water, gathering this data requires the use of lights.

A significant amount of work has been done in the study of underwater lighting to optimize light sources for underwater photography, television, and human observation. Many different lights have been developed, but only four basic types are being utilized to much extent at the present time. They are: the incandescent quartz iodide light, the mercury vapour light, thallium iodide light and the recently developed ballastless gas discharge lamp. Each of these lights have characteristics which optimize it for different underwater lighting applications.

It has been theorized and experimentally shown that mercury vapour and thallium iodide light sources have a distinct advantage over incandescent lights for underwater television and black and white photographic applications. This advantage is derived from the gas discharge lights' appropriate spectral characteristics and high lumen efficiency.

Incandescent lights, on the other hand, have advantages over the gas discharge lamps. Because of their high energy output in the red portion of the spectrum, they are one of the main sources of lighting for underwater colour photography. They also provide light immediately upon start-up, and have simple power requirements. Therefore, they are widely used for general underwater illumination.

The recently developed ballastless gas discharge light maximizes the advantages of both the incandescent and gas discharge lights while minimizing the disadvantages of each. A spectral output well-suited to the transmission characteristics of water is combined with high lumen efficiency, illumination immediately upon start-up, and simple power requirements. This paper will detail the operation of the new lamp, discuss the wide range of its application, and place it in perspective with other underwater illumination sources.

THE INCANDESCENT LIGHT

DESCRIPTION

The most common types of incandescent lamps used in underwater lighting applications are "Tungsten Quartz Iodide" lamps. These lamps are compact in size and offer greater efficiency than standard incandescent lamps. A 1000 watt incandescent lamp which is widely used for underwater lighting and photography is shown in Fig. 1.

The basic lamp consists of an outer pressure envelope, an inner quartz envelope which contains the filament, and a base for attaching to a waterproof socket.

The filament of a quartz iodide lamp is usually a coil of tungsten wire that increases the concentration of heat, thus increasing efficiency over standard wire filaments. The lamp's inner envelope is normally filled with an inert gas such as nitrogen which reduces tungsten evaporation, and allows higher operating temperature for the filament.

This lamp element (inner envelope) is normally mounted inside a glass pressure envelope as shown, which allows operation at the high pressures encountered in underwater operations. The outer housing (pressure envelope) is also filled with an inert gas, such as nitrogen, to allow optimum heat transfer from the lamp element.

THEORY OF OPERATION

The operation of all incandescent lamps consists basically of heating a coil of tungsten wire to incandescence. The unique aspect of the quartz iodide lamp is the iodine cycle. During this cycle, tungsten, which is evaporated from the filament, combines with the iodide vapour in the lamp and forms tungsten iodine gas. When this gas comes near the filament, the tungsten is separated out of the tungsten iodide gas and re-deposited in the filament. This frees the iodine to repeat the cycle. The advantage of utilizing the iodine cycle is that it almost eliminates bulb "blackening" and allows the quartz iodide lamp to operate throughout its life with over 90% of its original brightness.

The normal operating colour temperature of present day long-life quartz iodide lamps is 3000° K. Operating the filament at this temperature allows life expectancy in the order of 2000 hours. When an incandescent lamp is operated at a higher temperature, the results are shorter life. The typical life for a lamp operated at 3400° K is 10 to 20 hours. Fig. 2 is a chart showing percent rated colour temperature versus input voltage for a typical 120 volt quartz iodide light.

The advantages of operating at a higher colour temperature are: greater efficiency (lumens per watt), and more "white" light. As an example, a daylight "photo flood lamp" gives off a very white light at approximately 4800° K colour temperature and efficiency of 35.8 lumens per watt, compared to 15 lumens per watt for a standard incandescent lamp at 3000° K. The result though, is an extremely short life.

POWER REQUIREMENTS

Simple power requirements are one of the prime features of incandescent lamps. The filament will operate on AC or DC voltages, and no ballast (such as ballast used on gas discharge and fluorescent lights) is required. Most quartz iodide lamps operate from 120 volts for higher wattage (over 250 watts) and 28 or 12 volts for lower wattage types.

The main disadvantage concerning power with incandescent lamps is that the spectral output and illumination level changes considerably with dropping line voltage. To illustrate the change in output illumination level versus input voltage, tests were run with a 1000 watt incandescent lamp. Input power to the lamp was set at 100 and 115 volts, and output illumination measured. The output of the 1000 watt incandescent lamp at 115 volts was 4400 candlepower; at 100 volts the light output dropped to 2900 candlepower, or a drop of 34% for a 15 volt line voltage drop.

PRIMARY USES

The primary use of the underwater incandescent lights are for colour photography and general lighting.

Taking colour photographs under water is difficult due to the strong spectral selectivity of sea water, which attenuates light much greater at the red end of the spectrum. The incandescent lamp provides lamp provides good colour compensation in water due to its high energy output in the red portion of the spectrum. Tests have shown that good colour reproduction can be achieved at distances of about 10 to 15 feet, but beyond this region it becomes impractical to obtain good colour rendition even under ideal water conditions.

ADVANTAGES AND DISADVANTAGES COMPARED TO OTHER LIGHTS

A summary of the advantages and disadvantages of incandescent lamps for underwater use are listed below:

Advantages over gas discharge lamps

a. Low initial cost--Incandescent lamp systems are the least expensive in terms of initial investment;

b. Spectral output--The spectral output which is high in red energy is best for colour photography under water;

c. Simple power requirements--Power requirements are simple, and no warm-up time is required. The lamp element will operate on AC or DC voltage.

Disadvantages Compared to Gas Discharge Lamps

a. Low efficiency--Efficiency of an incandescent lamp is 12 to 20 lumens of light output per watt of power input. This is compared to approximately 50 lumens per watt for mercury vapour lamps, and 80 lumens per watt for thallium iodide lamps. This factor can be extremely important in underwater vehicles where power requirements are critical;

b. Spectral output--For general lighting, television, or black and white photography, the spectral output of the light is not optimum for transmission in seawater. Attenuation in water is high in the red energy region and lower in the blue-green, which allows much further viewing with mercury or thallium vapour lamps than with incandescent lamps in water;

c. Short life--The average life of modern quartz iodide lights is 1000 to 2000 hours compared to 8000 to 10,000 hours for mercury vapour lamps;

d. Spectral output and intensity change--Spectral output and intensity change considerably due to dropping line voltage compared to gas discharge lamps.

THE MERCURY VAPOUR LIGHT

DESCRIPTION

Mercury vapour lamps are classified as gas discharge lamps. There are two types of mercury vapour lamps; high pressure and low pressure. The common fluorescent lamp is an example of a low pressure mercury vapour lamp. In this paper, we will deal only with the standard, or high pressure mercury vapour light.

A 250-watt underwater mercury vapour light is shown in Fig. 3. A brief description of the basic elements of a mercury arc light follows:

Arc Tube

The arc tube confines the mercury arc and permits high temperature operation. This tube contains argon gas and a precise amount of mercury which determines the operating pressure of the mercury vapour, and thus determines the wavelength of the output radiation.

Main Electrodes

The main electrodes act as the terminals for the main arc during operation. During AC operation of the lamp, each half cycle, one main electrode acts as the anode, and the other as the cathode.

Starting Electrode

The starting electrode is the small electrode located near the bottom main electrode. This electrode strikes the initial arc with the lower main electrode to start the lamp.

Starting Resistor

The starting resistor limits current to the starting electrode to a low value during starting and operation of the lamp.

THEORY OF OPERATION

Mercury vapour lamps, as mentioned previously, are gas discharge lamps and, therefore, require an initial high voltage to ionize the gas in the arc tube and start the lamp. After starting, the mercury vapour lamp has a negative resistance characteristic and, therefore, needs a ballast transformer to limit the current to the lamp element. The ballast transformer also supplies the high voltage for initially striking the arc.

Referring to the block diagram in Fig. 4., the theory of operation of a mercury vapour lamp is as follows:

The arc tube of the lamp contains an amount of argon gas to aid in starting the lamp. When line voltage is applied to the ballast, a high voltage (approximately 280 VAC for 250 watt lamp) appears between the starting electrode and the adjacent main electrode. This voltage draws electrons across the short gap and ionizes some of the argon gas in the tube. The starting resistor limits the current to the starting electrode to a few milliamperes. This ionized argon gradually diffuses through the tube to the other main electrode. When resistance is low enough, an arc strikes between the main electrodes. The heat from the main arc vapourizes the mercury droplets in the tube, and they become current carriers in the main arc. After all the mercury is vapourized, the lamp is "warmed up" to its operating current (approximately 2.5 amps for a 250 watt bulb). The arc is then maintained across the main electrodes with its current limited by the ballast.

One main disadvantage of the mercury vapour lamp is that if the arc is extinguished by loss of power, it cannot be restored immediately. A cooling period is necessary to allow the mercury vapour to condense in the arc tube walls, lowering pressure sufficiently for the arc to be struck again. This cooling period is approximately 5 minutes for a 250-watt lamp.

POWER REQUIREMENTS

Most standard mercury vapour lamp systems require 115 VAC, 60 Hz input power to the ballast unit. As mentioned earlier, this ballast provides the high voltage needed to initially strike the arc and also limits the current to the lamp.

In most ballasts, current limiting is provided by either a choke or a capacitor. Because the reactance of the choke or capacitor regulates the current to the lamp, the frequency at which the system operates is critical. In other words, a 60 Hz ballast will not operate at 50 Hz, unless the L or C is adjusted to provide proper operating current to the lamp.

The AC power requirements for mercury vapour lights limited their use in underwater light systems because of the many applications where the only power available was from a DC source. However, a DC to AC inverter and ballast transformer is now available which allows operating of mercury vapour lights from 28 volts or 120 volts DC. This configuration is extremely valuable for use on submersibles where primary power is from batteries, since is allows the use of high efficiency mercury vapour lamps in areas where available power for lighting is extremely critical.

PRIMARY USES

The primary uses for mercury vapour lights are underwater television, black and white photography, and for general lighting. They offer many advantages over incandescent lamps. The primary ones being long life and lumen efficiency three or four times greater than incandescent lamps.

Mercury vapour lamps have been used with underwater television systems for many years. They offer high efficiency and a close spectral match to the sea water transmission characteristics. Since black and white television is a monochromatic system, colour rendition is not of prime importance. Also the overall television system may be further optimized through the use of the vid consensor which has a spectral sensitivity closely matching that of the water and mercury vapour lamp. As an example of this advantage, a 1000 watt mercury vapour lamp which is rated at 54,000 lumens (based on the spectral sensitivity of the eye) when used with a vidicon of selected spectral response, produces 79000 lumens in terms of TV camera sensitivity. This is almost 10 times more light than would be obtained from an incandescent lamp with equivalent input wattage.

The mercury vapour lamp has also proven to be a highly efficient source when used with black and white photography and general lighting where colour is not important.

ADVANTAGES AND DISADVANTAGES

A summary of the advantages and disadvantages of mercury vapour lights compared to incandescent light sources is listed below:

Advantages Over Incandescent Lamps

a. Efficiency--Mercury vapour lamps offer efficiency in the order of 50 lumens per watt compared to 15 lumens per watt for incandescent lamps;

b. Spectral Output--Mercury vapour lamps closely match the "optical window" of seawater, resulting in much greater visibility than the standard incandescent lamps. Also, the spectral output of the mercury vapour lamp does not change with dropping line voltage, as does an incandescent lamp;

c. Spectral output of mercury vapour lamps closely match vidicon sensitivity--The mercury vapour lamps closely match sensitivity curve of many vidicon tubes, making them extremely efficient for use with underwater television systems;

d. Long Life--Present underwater designs show possibility of life ratings as high as 10,000 hours compared to an average of 1000 to 2000 hours for incandescent lamps.

Disadvantages of Mercury Vapour Lamps

a. Higher Initial Cost--Initial investment, which will include a ballast unit, is higher than incandescent light systems;

b. Complexity--Mercury Vapour light systems are more complex, with each light requiring a ballast transformer-starter;

c. Special Output--No red energy is emitted from a mercury vapour lamp; therefore, no meaningful colour work can be performed;

d. Warm-up Time--Mercury vapour lamps require a warm-up time to come to full brilliance, approximately 7 to 10 minutes for a 250 watt lamp, and approximately 15 to 25 minutes for a 1000 watt lamp.

THE THALLIUM IODIDE LIGHT

DESCRIPTION

Thallium iodide lamps are basically gas discharge mercury vapour lamps with the addition of thallium meta to the high pressure mercury discharge. The thallium light provided a significant breakthrough in matching its illumination spectrum to the 5100A window in the water transmission spectrum. It also provides lumen efficiences in the order of twice that of mercury vapour lamps. Construction is the same as the mercury vapour lamp (see Fig. 3).

THEORY OF OPERATION

Thallium iodide operates on the same principle as the mercury vapour lamp. The main difference is the action of thallium atoms in the gas discharge. With thallium concentrations in the order of only 0.1 per cent that of mercury, the thallium light output radiation is readily apparent in the spectral output of the lamp, with the principle line of thallium at 5350 Angstroms. Since this line is very near the peak of the eye sensitivity curve, (about 90% of the peak value), its radiation greatly improves the efficiency of the discharge.

The relative outputs of mercury vapour and thallium iodide operating at 250 watts are shown in Fig. 5. For a detailed explanation of the thallium additive process, see "Higher Efficiency Light Source Through Use of Additives to Mercury Discharge"; this paper is listed in the references.

POWER REQUIREMENTS

The power requirements for thallium iodide lights are the same as for mercury vapour lamps. In fact, an important consideration in the development of thallium lights was that they be capable of operating from standard mercury vapour ballast transformers.

PRIMARY USES

The thallium light appears to be an extremely useful light source in the same areas where mercury vapour lights are used. They offer higher efficiency than the mercury vapour light, and an even closer spectral match to the sea water transmission characteristics.

Although the colour output of the thallium light is basically green, the colour rendition of objects illuminated by the lamp is about the same as a colour corrected mercury vapour lamp, with about 5 per cent of the output in the red. Although still unusable for colour work in water, future developments in metal additive lights could provide higher luminous output combined with a substantial improvement in colour rendition.

ADVANTAGES AND DISADVANTAGES

Advantages Compared to Other Lamp Sources

a. Efficiency--The thallium iodide lamp is almost twice as efficient as a standard mercury vapour lamp--in the order of 75 lumens per watt. This makes it 4 to 6 times as efficient as standard incandescents;

b. Spectral Output--The spectral output contains most of its energy in the green region (5300 Angstroms) which matches it to seawater even closer than the mercury vapour lamp;

c. Other Advantages--The thallium iodide light has the same advantages over incandescent lamps as the mercury vapour.

Disadvantages of Thallium Iodide Lamps

a. Because the thallium light is a gas discharge lamp and needs a ballast transformer-starter, it has the same disadvantages in this respect as the mercury vapour lamp.

THE BALLASTLESS GAS DISCHARGE LAMP

DESCRIPTION

The ballastless gas discharge lamp combines the best features of both the incandescent lamp and the mercury vapour lamp.

The standard gas discharge lamp relies on a high initial voltage and ionization of an inert gas such as argon for primary ignition. This higher voltage and dramatic load change requires the support of a ballast system as described in Fig. 4.

The ballastless lamp, however, utilizes a miniature tungsten filament inside the inner glass envelope for heating and ionizing the gas, and a larger tungsten element in the outer element to provide a means of current limitation during the start-up period of the lamp.

A basic 300 watt underwater mercury vapour ballastless light is shown in Fig. 6. A brief description of the operating elements of the lamp follows:

Arc Tube

The arc tube houses the main electrodes and starting filament for the gas discharge element. It is normally filled with an inert gas such as argon as a means to initially ionize and provide electron blow between the main electrical elements.

Main Electrodes

The main electrodes provide the conduction terminals for the current arc during lamp operation. During initial start-up these electrodes are short-circuited via the thermal switch and remain this way until the lamp has warmed sufficiently to support the gas arc.

Starting Filament

A small thoriated tungsten filament is installed in the base of the arc tube and provides for the initial heating of the gas for arc ignition. This small filament acts, in part, to reduce the necessity for a high potential difference, which is mandatory in the standard mercury and thallium ballast type discharge lamps to initially strike the arc and lower the lamp's impedance. This small filament is located at the base of the arc tube and is electrically connected to the leg of the main electrode.

Ballast Element

The ballast element is simply a tungsten filament element connected in series with the supply line on one of the main starting electrodes of the gas discharge lamp. It provides a means of absorbing the current fluctuations during initial turn-on and striking of the arc. It also has the purpose of providing immediate illumination once power to the lamp is activated. The ballast element is mounted inside its own sealed quartz envelope and lies physically in parallel with the gas discharge lamp element.

Thermal Switch

A thermal switch is provided to open-circuit the small starting electrode and the ballast element once the gas discharge lamp has warmed up to full operating power.

Outer Pressure Envelope

An outer pressure envelope is constructed to house the components of the ballastless lamp and provide for water integrity and the lamp's ability to be operated in considerable depth in water. The outer envelope is a quartz material and also provides good thermal transfer from the lamp elements to their colder water surroundings. This is of prime importance during high thermal shocks experienced during operations in the ocean environment.

THEORY OF OPERATION

Fig. 7 details the operation of the ballastless gas discharge light. When initially energizing, the thermal switch is closed allowing current to flow through the main tungsten filament and the small thoriated tungsten filament. This current flow provides an immediate high illumination source (utilizing tungsten filament). The smaller filament heats up the evacuated arc tube or inner envelope, vapourizing the mercury droplets and increasing the tube pressure. After sufficient heating (approximately 3 to 6 minutes), the mercury vapour provides sufficient conduction for the gas discharge lamp to become operational. This process is aided by the electrons made available from the small thoriated tungsten filament. The increase in temperature of the tube now causes the bi-metallic switch to open, thus releasing the large and small tungsten filaments from the circuit.

Once extinguished, the lamp must be allowed to cool, closing the bi-metallic switch and reducing the pressure in the inner envelope in order to permit a further lamp open cycle. This cooling process is approximately 2 to 4 minutes and is dependent on the environmental temperature outside the lamp.

POWER REQUIREMENTS

The standard ballastless lamp system will operate from 115 volts AC or 115 volts DC and needs no external ballast. The spectral output of the lamp is relatively insensitive to frequency changes and provides an immediate source of illumination from the tungsten element once the power is applied. At normal operating temperature, the supply voltage may be reduced to 65% of its rated value without extinguishing the lamp. Below this threshold, there is insufficient potential difference to maintain the gas arc and the light will go out. However, between 65 and 100% values, this lamp provides a means of variable illumination which is of advantage in turbid or highly reflective viewing situations. In these instances, backscatter restricts the use of full power illumination. Overall, power drain is approximately uniform from initial starting until fully operational. Fig. 8 depicts the power curve against time

PRIMARY USES

The ballastless gas discharge lamp may be used for almost all underwater lighting applications. It offers the advantage of immediate start from the incandescent element and the long life and lumen efficiency of a marcury vapour source. Once at full operating temperature, the incandescent element is open-circuited and the lamp reverts to the power-saving operation of a standard gas discharge lamp. At this point, its spectral output is in the region of 5200 Angstroms, thus making it more suitable for black and white television, photographic applications and penetration of the seawater environment. It shares the other major advantages of both the thallium and mercury lamps. Additionally, it may be used in applications where a DC supply or poor frequency regulated supply is available.

ADVANTAGES AND DISADVANTAGES

Advantages

a. No External Ballast Required--the ballastless lamp requires no form of external ballast and may be operated from a standard 115 volt power outlet;

b. Instant Light Source--The incandescent element housed within the lamp provides an immediate source of illumination and remains in circuit until the gas discharge lamp is fully operational;

c. AC or DC Operation--The ballastless lamp will operate from both 115 volt AC or 115 volt DC and is insensitive to frequency fluctuations;

d. Variable Light Source--Once fully operational, the amount of illumination from the ballastless gas discharge lamp can be varied simply by lowering the supply voltage. The lamp can be operated at 65% to 100% of the rated voltage without a detrimental effect to the bulb;

e. Efficiency and Spectral Output--The efficiency and spectral output offer the same advantages as do the standard mercury and thallium gas discharge lamps;

f. Low Initial Cost--Since no external ballast is required, the initial cost of a ballastless gas discharge lighting system is lower than that of a conventional mercury vapour or thallium iodide system.

Disadvantages

a. Spectral Output--Once at full operational temperature, there is no red energy emitted from the lamp; therefore, no meaningful colour work can be performed;

b. Cool Down Period--Once extinguished, the lamp requires a cool down period, as do the standard mercury and thallium gas discharge lamps, before re-starting occurs.

ALTERNATE CONFIGURATIONS

The present ballastless lamp design could be configured with a thallium bulb in place of the mercury bulb. However, as the thallium element is slightly larger than the mercury element, this configuration would require larger outside bulb dimensions.

Yet another slightly different approach is to combine the incandescent and gas discharge bulbs in a series arrangement and take advantage of both the colour balanced output of the tungsten lamp and the penetration and lumen efficiency of the mercury or thallium output. Fig. 9 shows this configuration which is currently under prototype evaluation.

In this mode of operation, a higher supply voltage is applied to the lamp (typically 220V AC or DC). When initially connected, the full 220V appears across the gas discharge element--its impedance being such that current through the circuit is very low and voltage drop across the tungsten element is very small. As the arc lamp begins to function, ionization commences. Its impedance then begins to fall, and more voltage is distributed across the tungsten element. This self-regulating process continues until the gas discharge lamp is fully operational, at which point it shares the voltage supply with the tungsten lamp. The ratio of voltages is determined by the tungsten element and the small current limiting resistor. The design approach is to have full supply voltage initially across the gas discharge lamp (115V AC), then construct the tungsten filament impedance such that it will operate on a lower voltage so that the current-limiting resistor can be made to limit current without absorbing excessive power.

Fig. 10 is a current/time graph showing the relatively constant current drain on the lamp combination. This steady requirement and unique start-up load cycle eliminates the need for an external ballast and suggests a wide selection of applications for this type of lamp. As the need for underwater colour reproductions is increased, so too will the demand for a wide spectrum light source. The ballastless quartz/mercury lamp is one such source.

FUTURE LAMP DEVELOPMENT

The introduction of coloured lasers and higher efficiency sources of underwater lights is a must in the increasingly expanding exploration of the world below the sea.

Many companies are pursuing the development of this field with the hope of a breakthrough, particularly in respect to utilizing "cold" light sources. These sources provide a much higher ratio of light to heat than is currently available from either incandescent or gas discharge sources. Deeper requirements and operation from low-power submersibles mandate the need for low power, high efficiency sources. It is hoped that the ballastless gas discharge lamp is furthering these goals.

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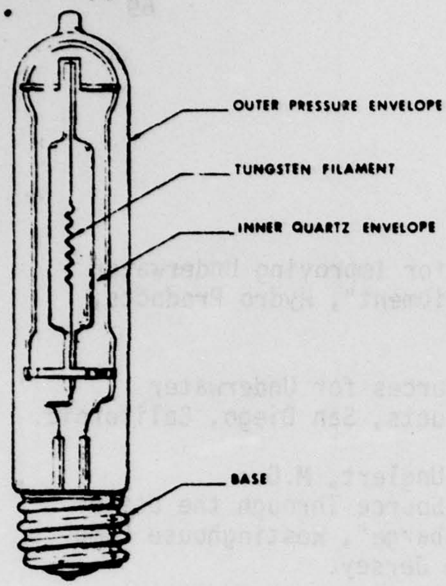


FIG. 1 - QI-1000 QUARTZ IODIDE LAMP.

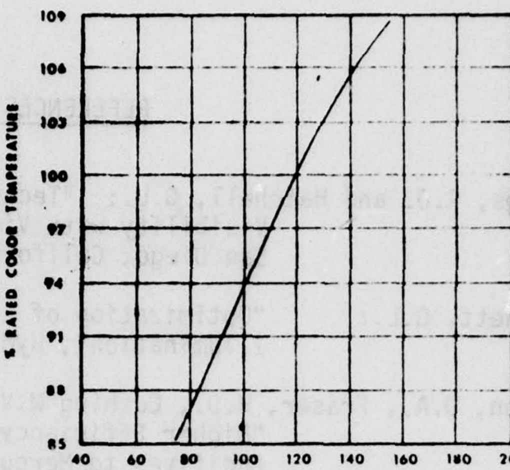


FIG. 2 - COLOR TEMPERATURE VS. INPUT VOLTAGE--120V QUARTZ 120V QUARTZ IODIDE LAMP.

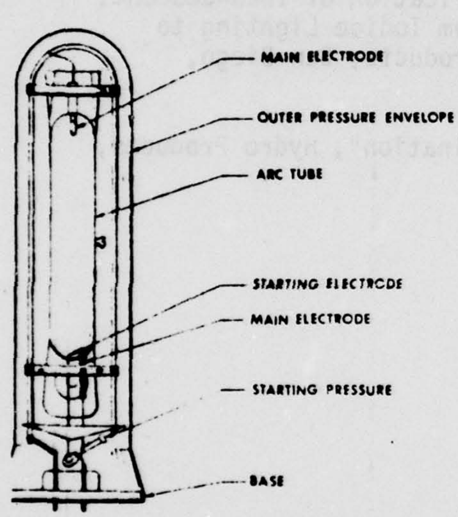


FIG. 3 - GAS DISCHARGE LAMP.

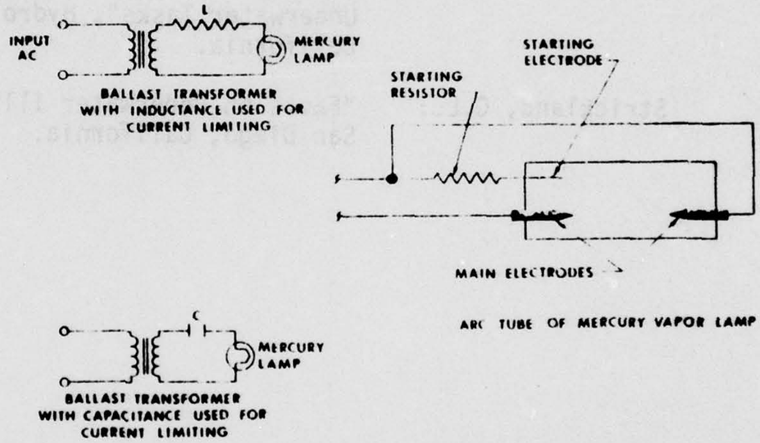


FIG. 4 - GAS DISCHARGE LAMP.

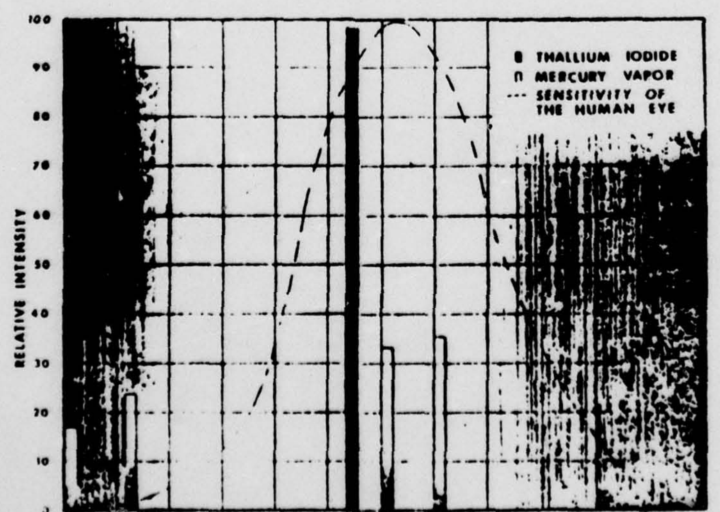


FIG. 5 - SPECTRAL INTENSITY GAS DISCHARGE LAMPS.

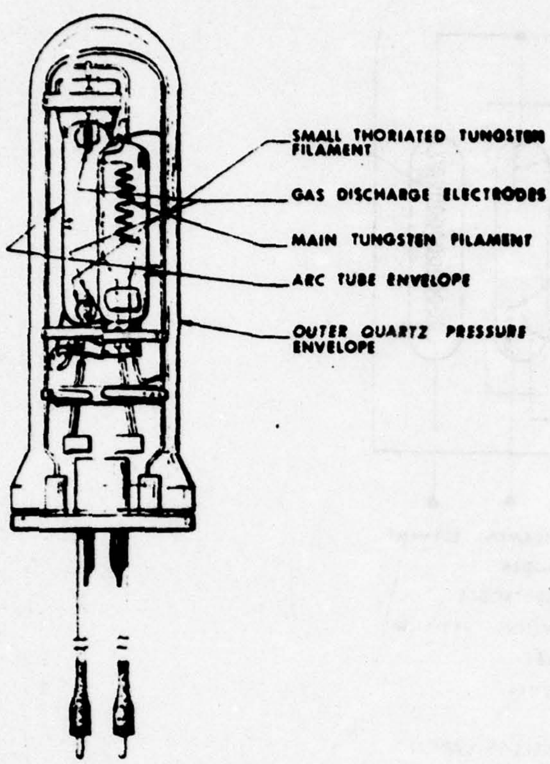


FIG. 6 - BALLASTLESS GAS DISCHARGE LAMP.

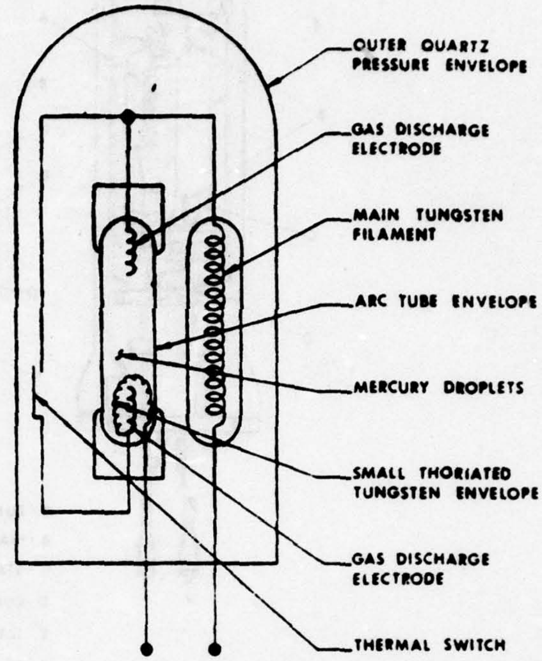


FIG. 7 - QM-7 BALLASTLESS GAS DISCHARGE LAMP.

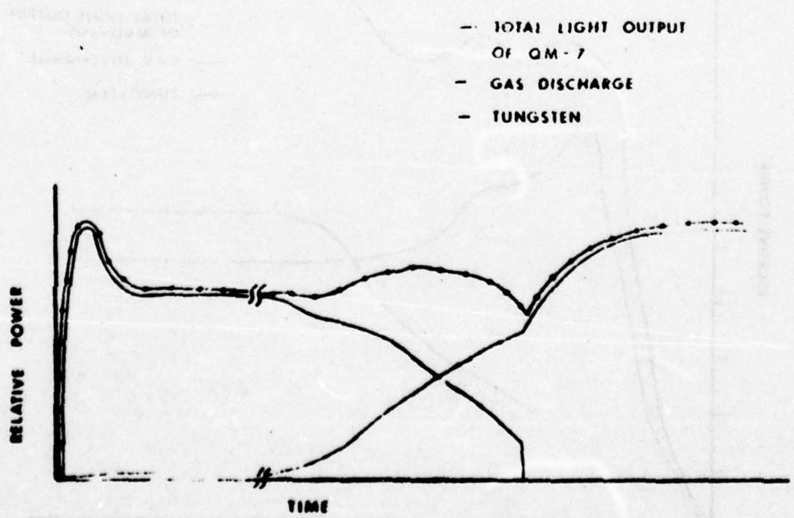


FIG. 8 - LIGHT OUTPUT - QM-7 LAMP.

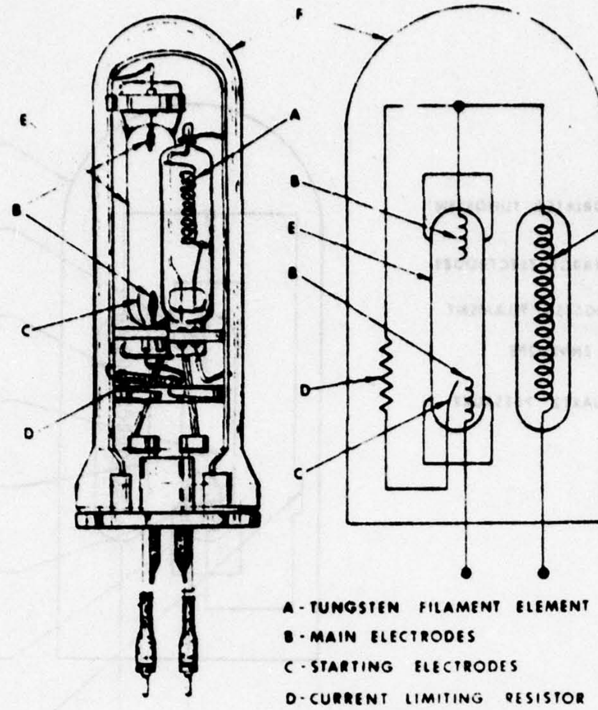
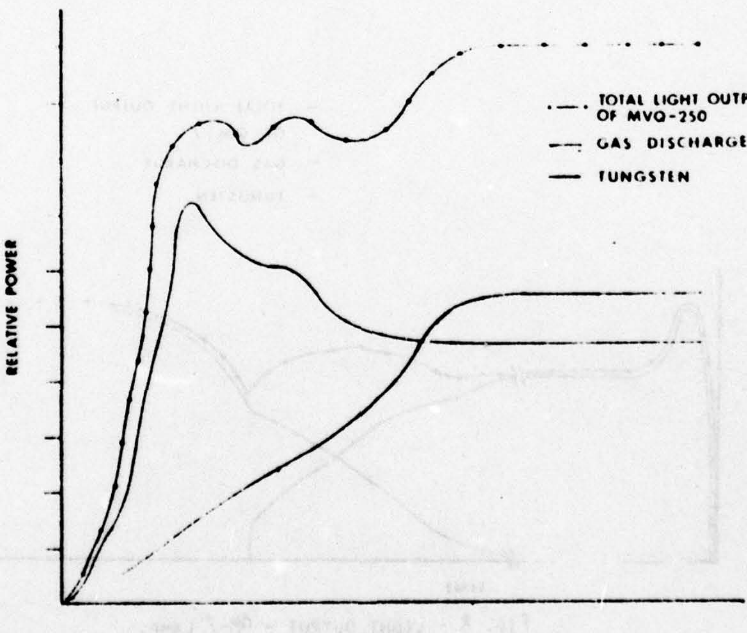


FIG. 9 - MVQ-250 BALLASTLESS LAMP.



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EXCAVATION OF THE SAPPHIRE, A 1696 BRITISH FRIGATE

By

Mr. P. Waddell

Department of Indian and Northern Affairs

During the spring of 1977, an agreement was reached between the Federal Government and the Province of Newfoundland which permitted a preliminary underwater archaeological excavation on the site of the SAPPHIRE in Bay Bulls, Newfoundland. An archaeological team from the Research Division, National Historic Parks and Sites Branch, Parks, Canada, Department of Indian and Northern Affairs provided the site direction.

Bay Bulls is located on the Newfoundland coast approximately 40 kilometers south of the city of St. John's. It was here that the 32-gun 5th rate British frigate was sunk. According to historical documentation, the shipwreck was the result of a direct engagement with French forces in the bay. No references were found to indicate any attempt at contemporary salvage. Hence, it was anticipated that a variety of cultural remains would be left intact where the ship lay in 60 feet of water. However, during the 1960s and early 1970s, the site suffered considerable disturbance when a number of cannon and artifacts were recovered. When the Newfoundland Marine Archaeology Society undertook a trial excavation in 1974, interest in the SAPPHIRE site intensified.

The Parks Canada underwater work began in Bay Bulls in August, 1977 following extensive preparation of the surface support craft. Two wrecks known to lie in the vicinity of the SAPPHIRE were investigated briefly. One wreck consisted mainly of an extreme lower section of hull with considerable ballast stone and very little cultural material. The other wreck containing three cannon was more thoroughly buried leaving greater structural remains. Test pits excavated on this wreck uncovered barrel staves as the primary material on the site. Although few cultural remains were found on these wrecks, it was possible to determine and record their orientation which had not been done previously.

Most of the team's efforts were then concentrated on the wreck of the SAPPHIRE. Initially, a datum line was established along the length of the keelson. Approximately two meters of the keelson was visible just aft of the bilge pump box. A line was extrapolated into the bow region of the hull and a test trench dug at that point. The keelson lay some 60 centimeters below the seabed. Fortunately, enough of the stern was exposed to establish the reference datum in this area. A datum line was then installed from one end of the overt wreckage to the other. This allowed the placement of grids for controlled excavation and mapping purposes.

Three major trenches were dug on the vessel; in the stern, midships, and in the bow area. The stern trench afforded initial investigation of the stern deadwood. The base of the rudder and sternpost mortise were uncovered and recorded along with other structural details. This trench also revealed a distinct stratigraphy featuring a fish bone layer of varying thickness which had apparently been crushed by the keel of the vessel. This proved a valuable bases for inferences regarding temporal deposition of cultural material. A wide assortment of artifacts was recovered as well from the stern, including a nocturnal (a 17th century navigational device), a cannonball or shot gauge, measuring weights and a variety of ceramic materials. Ceramics from the SAPPHIRE comprised different types of coarse earthenware, tin glazed earthenware, and stoneware as well as bricks and tiles.

In the second trench across the midships immediately aft of the bilge pump box, a section of hull 4.5 meters wide was encountered. The excavation was extended well beyond the extant hull and considerable cultural material was recovered. In the port midships trench which was left unexcavated, a small anchor was located. Although the ring was wrapped with concreted material and only a small portion of the shank was exposed, the morphology of the anchor would indicate that it was likely associated with the SAPPHIRE.

The bilge pump box in the midships region remains relatively intact and affords an excellent opportunity for the study of this particular architectural feature. Although the box was left unexcavated to maintain its structural integrity, measurements obtained from the region will permit a preliminary surface drawing of the pump box. The bilge pump bases or stumps are also intact and can be tied into the overall structure for more detailed study.

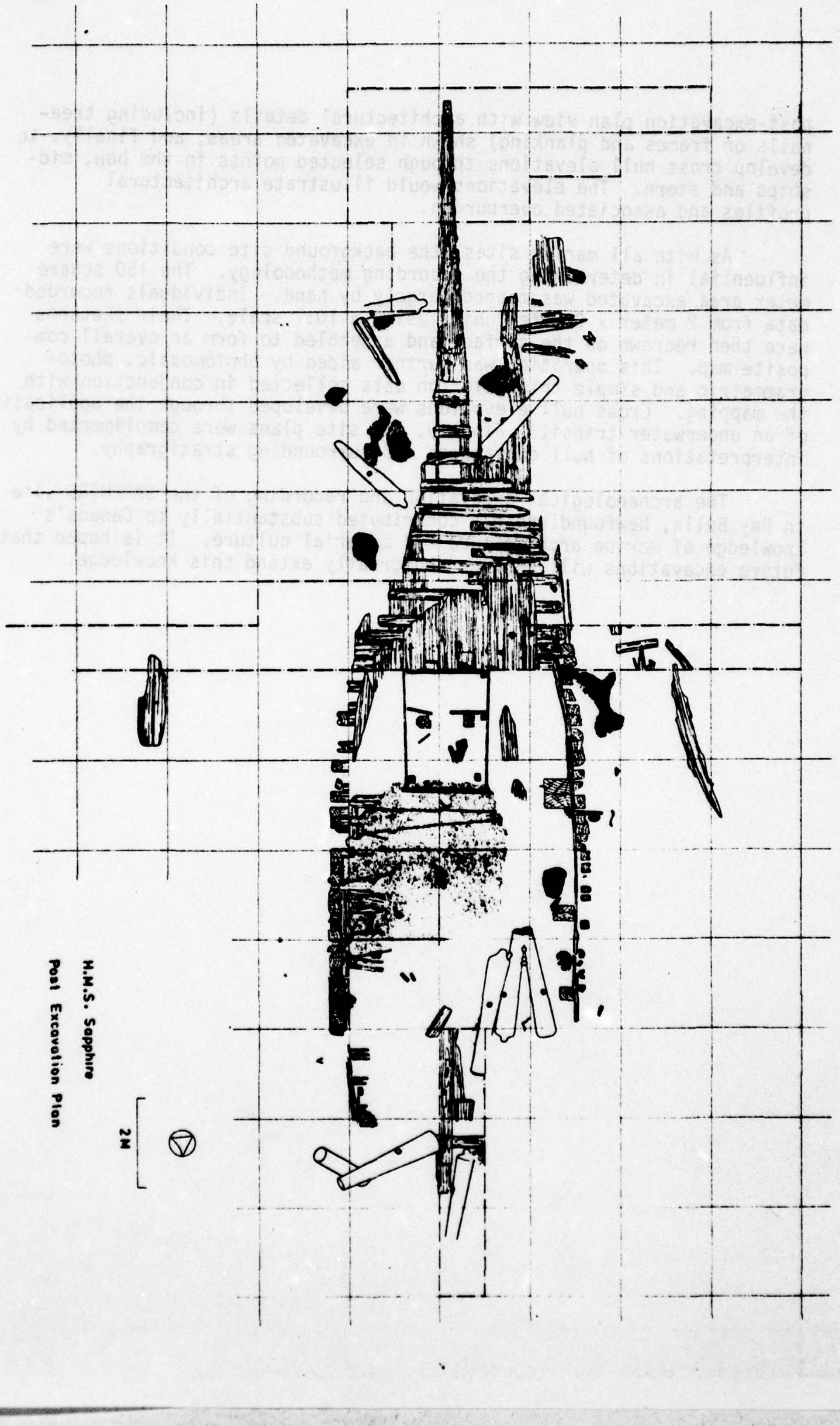
In the bow region, eight meters north of the pump box, a trench was dug to establish the datum reference, to determine the amount of cultural material in this section, and to record the extent of remaining bow structure. Further excavation eastward toward the bow revealed that the keelson, which was partially obscured by a previously uncovered cannon, terminated in a scarph joint of the hook type. The primary overburden in this region consisted of tightly-packed coarse gravel as opposed to a definitely "softer" three layer stratigraphy in other parts of the vessel. Digging was therefore, slow and no further bow structure was uncovered beyond the final keelson scarph. Although it is likely that major bow structural remains are extant, shortage of time prohibited closer investigation of this region.

Concurrent with the excavation was undertaken an intensive program of site mapping. The three main objectives of the mapping were: to develop an initial "as found" plan view of the site showing the outline and major features of all observable wreckage; secondly, to complete a

post-excavation plan view with architectural details (including tree-nails on frames and planking) shown in excavated areas; and finally, to develop cross hull elevations through selected points in the bow, mid-ships and stern. The elevations would illustrate architectural profiles and associated overburden.

As with all marine sites, the background site conditions were influential in determining the recording methodology. The 150 square meter area excavated was mapped largely by hand. Individuals recorded data from 2 meter x 2 meter units using a 10:1 scale. Their sketches were then redrawn on the surface and assembled to form an overall composite map. This operation was further aided by photomosaic, photogrammetric and simple triangulation data collected in conjunction with the mapping. Cross hull elevations were developed through the application of an underwater transit. Finally, the site plans were complimented by interpretations of hull curvatures and surrounding stratigraphy.

The archaeological excavation and recording of the SAPPHIRE site in Bay Bulls, Newfoundland has contributed substantially to Canada's knowledge of marine architecture and material culture. It is hoped that future excavations will enhance and greatly extend this knowledge.



H.M.S. Sapphire
Post Excavation Plan

MAN UNDERWATER, MEDICINE AND MIRACLES

By

M. Lepawsky, M.D.

In 1973, Canadian diving was obliquely charged to "achieve an internationally recognized ability to operate below Arctic ice" within 5 years. By 1973 some notable Canadians had, of course, proven their ability to do that and much, much more with vitality, vigour and vengence. The dynamic lead of the Canadian Diving Community could well be emulated even now in 1978, five years after this anachronistic challenge was presented.

Manned underwater work seems of less popular concern than environmental pollution, unemployment, inflation, energy crises and nutritional deficits. Truly, these problems are on the verge of destroying us. But they are only symptoms of deeper and more serious issues. And all this does seem far removed from the activities of man underwater and medicine and certainly from miracles.

But mankind needs some miracles right now. If we don't get some miraculous solutions to the problems just mentioned, societies will soon no longer be sociable and governments aren't going to have anything to govern. Man underwater may offer some answers.

Be that as it may, medicine as a discipline accepts many inappropriate popular misconceptions such as that the state of the art of Canadian diving is far in advance of where public opinion thinks it is. Physicians concern themselves with serious pathologies and diseases, some of which, result partly because of supposedly more important issues than manned underwater work.

Some diseases of concern are well known to you all. They are the big killers, disablers and enemies of planning, productivity and progress. They are cardiovascular diseases involving the heart and blood vessels, cancers, strokes, diseases of the respiratory system, homicied, suicide, cirrhosis, accidents including motor vehicle accidents, falls and drownings and other pathologies.

Yet these diseases can have certain of their roots in environmental causes, unemployment, inflation, dysnutrition and energy misutilization. Manned underwater work could solve these, or help to do so.

Look at unemployment as an example. This malady devastates the self-image of the unemployed. Heavy alcohol, tobacco and other abuses are frequent resultants. These abuses heavily contribute to and influence or mortality and morbidity statistics. Favouring such abuse, unemployment may increase mortality and morbidity...and certainly taxes.

So much for medicine and unemployment. Let's look at man underwater and unemployment. With full recognition of underwater resource potential, without misapprehension about state of the art Canadian manned underwater work, could Diving Community be helped to dance more easily to the music it hears and the rhythms it understands then surely that vigour and commitment which allowed Dr. MacInnis to phone Prime Minister Trudeau from under Arctic Ice in December of 1972 could be harnessed to, just as an example, increase the number of jobs available. And I know many divers capable, willing and anxious to take those jobs and do them well. That's a good reason for paying more attention to manned underwater work.

That's one miracle man underwater could accomplish....creation of more avenues for increased productivity...that is, more work, more jobs, more monetary exchange. The effects on the economy, unemployment and inflation are easy to predict. And clearly with more employment, particularly underwater, fewer impaired self images and less self abuse would result. Decreased mortality and morbidity would permit more money to be spent developing and nurturing the underwater environment. So much for man underwater and unemployment.

There is a story about a supposedly self-employed diver which well describes the problem of self-abuse amongst those of us who work for a living. Its ultimate outcome dramatizes a truly miraculous combination of self abuse, man underwater and medicine in its purest and most productive sense.

But before the story, let's look at self-abuse amongst the employed. Large numbers of us work of course. And even some creative citizens indulge themselves shamelessly in behavioural patterns resulting in early, sudden deaths, chronic disabling diseases and unhappy periods in what should have been long rewarding, happy lives.

A physician need not tell you that, truly, could a way be found to stop such patterns, our mortality and morbidity statistics would be hugely and favourably improved and altered. So much for self-abuse amongst the employed.

But here's the story of a man underwater, self-abuse, medicine and a miracle. Not too long ago, a group of physicians trained here at DCIEM, a medical mecca, as far as I'm concerned, found a way to stop horrendous self abuse in a diver who so disrespected his fate of being human he almost killed himself with the effervescent effects of bubbling nitrogen because of supersaturation on returning to his usual ambient atmospheric pressure after working at depths said to have been as deep as 250 feet on his second dive where he stayed for 20 minutes, ran low on air...yes, I said air at 250 feet, and had to ascend rapidly. His first dive had been to 130 feet for 20 minutes and the surface interval was seven minutes after a four minute ascent.

By all this it is meant to inform you that this crazy bugger nearly killed himself with bends. He would have died if it hadn't been for DCIEM trained personnel and some of the most skilled diving accident and decompression sickness treatment team members in the world.

Ol' John, his name wasn't really John, but I changed the name here so I could indict the guilty...Ol' John was a helluva diver. Just ask him, he'd tell you. Ol' John dove with triple 80's, an untended topside compressor and a Rat Hat. He'd hang the hat off a boat and leave it to decompress with. Mind you, Can-Dive doesn't know where Ol' John got a Rat Hat but he by God had amongst other untended equipment, a Rat Hat. Now you might say, "so what?" And if so, I want you to ask Don Leo Johnathan how he intends to straighten Ol' John out (bends and all).

But be all that as it may, Ol' John was going to jack hammer some holes in a big ol' rock. Later he was going to attach some shackles to some nearby cement block moorings.

Let me say here that Ol' John doesn't wear a watch or a depth gauge. So, Ol' John goes by guess and gosh. It isn't that Canadian Thin Films is unknown to him; it's just that machismo so blinded this man, that he knew he could go ahead with a dive profile guaranteed to kill a lesser man...like me, for example, if I'd have tried Ol' John's style, I'd have died...no question...I'd a been toes up.

But not Ol'John...no way. Ol' John, he could disprove Haldane, Benkhe, Kidd, Stubbs, Bert, Priestley, MacDonald, Nuytten, Cox, Kylstra, Buckingham, Bennett...and Fortin. Now anybody can try the others without fear. But when you start on Fortin...look out.

Right, well this guy shorts himself by some sixty minutes of decompression time at various depths. He surfaces, has three beer, two glasses of tomato juice. Three and one-half hours after coming up he's reported by passing divers to be lying by the side of the road and gets picked up by the cops. He tells them he's been diving and he winds up at the recompression chamber.

Well, then starts a treatment profile consisting of one Table 6A, one Table 6 British Ascent modified by HeO_2 and N_2O_2, two Table 6's and two Table fives. Above and beyond this intensive care, with electrolyte, fluid and plasma management and other resuscitative techniques were required over an eight day period. All that and a lot of prayers.

To make a long exciting medical case history short, Ol' John beat the grim reaper by the bare bends of his bubbles. Then he later nearly died of liver failure because of his chronic alcohol abuse and the stress of the treatments. And it turns out he's diabetic!

So there's part of the miracle; that is, this guy lived! Right, well he comes back to see the treatment team after a while, to say thanks, having lost 25 lbs, quit drinking and smoking, appreciative to a fault and looking great. And that's the other part of this miracle..having confronted death in a scenario of his own creation, and been successfully rescued from it by a compassionate advanced state of the art treatment team...Ol' John got the point. He figured it out. He's a human being here by the grace of God. So he quit trying to kill himself, quit drinking, quit smoking, lost weight and from what I hear, he's diving again.

Now, that's a miracle. Ask most doctors. They should agree. Anything that can stop a patient's heavy drinking, smoking, overeating and self abusing is a miracle. Here's a case where man underwater got a miracle by medicine. Thank diving, thank the treatment and thank God for it.

Now if that could only happen across the board then we could improve those mortality and morbidity statistics. We'd have better health, more money and more human recourses to develop our underwater potentials.

So much for man underwater, medicine and one miracle. Well, it's child's play to develop similar scenarious for environmental pollution, inflation, energy misutilization and nutritional crises.

But I want to talk about another miracle. Man underwater fits into it well, though medicine does so rather marginally at present.

Let's look at man underwater in the Arctic. To this point in time, I can tell you of nearly 1600 Arctic dives with bends incidence of less than 1.0%. All cases so far have been minor, pain only, Type I decompression sickness...knock on wood. All responded well to treatment.

Now the guys who achieved this are very self-effacing about it. The significance of it is that this is as clean a record as can be found round the world as far as I can determine at this point. It is especially important to note that these series were run in the coldest waters of the world, the most hostile climate in the world, with ice the predominant and pressing fact of the environment. Hypothermia is a

constant parameter favouring decompression sickness. North Sea work cannot touch this record...knock on wood.

Furthermore, this series includes some extreme exposure times and work at depths now pushing to 250 feet. Saturation was a near requirement this summer. Added to the climatic challenge, the temperature factor and pressing ice conditions, the diving teams have the stress of knowing that millions of dollars would be lost if their mission failed.

That man (and ultimately women) can survive, be productive and enjoy themselves under such conditions of physiological and environmental challenge speaks to the genius of our Creator. That this is the case with little need for medical support to this point.in time (and I hope this continues) is one miracle of man underwater. Modern mankind at dry, atmospheric conditions in comfortable cities or outlying agriculatural areas should take note.

That's one of the best things about most divers...their ability to act independently, safely and sanely in an environment more challenging than topside.

This Arctic series has been in pursuit of petrochemical, hydrocarbon energy source exploration and factual scientific research. It has been planned and achieved by some outstanding Canadian Diving Community members. This community has more than responded to the challenge offered it to achieve international repute for being able to operate under Arctic ice. Now, let this community offer a challenge.

The challenge is this. May priorities please be made of issues concerned with nurturing progressive, productive civilizations. Preeminent, ebulient, productive civilizations have historically advanced by increasing and mastering innovative technological capabilities. These have permitted extension of utilizable environmental parameters.

May it please be remembered that technological advance and sound environmental exploitation require atmospheres conducive to exploration, free expression of thought, free enterprise and uninhibited experimentation. The enterprise required to produce such advance and exploitation has profoundly influenced national securities, economics, politics, societies, futures and international affairs. The nature of the enterprise of mankind has and will be heavily determined by the societal systems which produce the civilizations within which we live. May those systems evolve towards humanism, empathy and compassion.

The needs and potentials of diving community and manned underwater work should be looked after more attentively. In a more responsive setting the diving community could creatively resolve problems like the ones mentioned. It is already a model by which these symptoms of societal pathology can be partially erased. The expertise is right here in this room. You are it.

Medicine stands ready to offer what assistance is required for man underwater. Mankind under water has worth and significance so well proven that I, at least, am willing to call this the medicine required to achieve some miracles we need right now.

Let the model of the miracle of mankind underwater be examined and emulated. More mankind underwater is the prescribed medicine required to produce some of the miracles we so urgently need.

(Slide) This is the backside of the moon. Billions were spent to get us there.

(Slide) This is the first foot print of man on the moon. Billions were spent to get us there.

(Slide) This is us. (Slide of the earth).

(Slide) This is Vancouver Island, the Straits of Georgia and Puget Sound.

(Slide) This is Hudson's Bay.

(Slide) Underwater action shot.

NOW LET'S GET TO IT.

(Slide) Underwater action shot.

WE CAN DO IT.

(Slide) Underwater Action Shot.

AND IT'S UP TO US.

So much for mankind underwater; so much for medicine; so much for miracles. And so much for my address to the Third, and most stimulating, Canadian Underwater Symposium.

I thank you.

DIVING OPERATIONS IN SUPPORT OF ARCTIC OFFSHORE OPERATIONS

By

Mr. M.K. El-Defrawy, P.Eng.

Department of Indian and Northern Affairs

Offshore Diving Operations in the Canadian Arctic

Arctic offshore exploration activities can be divided into three essentially different geographical locations: the Beaufort Sea area (Western Arctic), the Lancaster Sound - Davis Strait area (Eastern Arctic) and offshore the Arctic Islands.

The diving operations required in support of such offshore activity differ according to the geographical locations as follows:

Offshore the Arctic Islands

Panarctic Oils Ltd. introduced the idea of drilling in the Arctic Islands offshore areas from a thickened ice platform built on top of natural sea ice during the winter season. Starting with the first such platform (Hecla N-52) Panarctic had to use divers periodically for shallow work under the ice. An example of this was the connection of the auxiliary cementing line (which was tied to BOP well-head while lowering it into position) to a cementing station some 500 ft. away from the rig. The shallow diving operations on other ice platforms (water depth at this site is 130 m) was mainly salvage work that was completed without any problems. Use of shallow diving operations under ice in support of offshore activities is expected to continue in the future as offshore operations proceed.

During the Drake offshore completion operation a recompression chamber was available for free swimming divers working in depths to 180 feet of water. In this operation the divers provided reconnaissance capability and performed minor tasks on a job which was essentially diverless.

For the purpose of deep diving operations, Panarctic conducted a trial of the "JIM" diving system in approximately 900 feet of water from an ice platform. The "JIM" system is ideal for Arctic work. It is readily transportable by air and it is effective for water depths expected to be encountered in Panarctic's operation (it was tested lately to 1500 ft. of depth). The area where the system was tested had very low currents and the diver in the "JIM" equipment was capable of performing any task required of him. The diver was not exposed to pressure and thus could surface directly to the surface without decompression. In the

event of malfunction of subsea equipment and the need for diver services in water depths exceeding 180 feet, Panarctic would expect to utilize the "JIM" diving suit to make the appropriate repairs/alterations. Panarctic Oils is of the opinion that the "JIM" system can perform all tasks which they expect in the future (in their area of operation) without any need for submersible diving chambers (this is due to generally low currents under the ice that have been observed till now and which contribute to high diver mobility and visibility.).

Western Arctic (Beaufort Sea Area)

The operator in charge of drilling activities in this area is Dome/CanMar and they use Can-Dive Services Ltd. of Vancouver, B.C. to carry out diving operations required in support of their drilling program conducted by three drillships, The Explorer I, II and III. Diving operations are required for general inspection of the sea floor site locations, observations of wellhead equipment and the recovery of drilling equipment. Actual tasks on undersea equipment include the replacing and attaching of guidelines plus maintenance and repair work. In addition, diving operations are required in support of setting and retrieving ship anchors as well as inspection and surveys of certain locations (as in the case of water flow from the Tingmiark K-91 and Kopanoar D-14 wells).

The diving systems available on the Explorer I and II are rated to water depths of 600 feet while the system used on the Explorer III is rated to water depths of 1000 ft. To date, the majority of dives made have been in water depths of 130 feet to 210 feet of sea water.

Diving operations in this area could be divided into three categories:

a. SCUBA type diving operations which are carried out in shallow water depths to check such items as the top part of the Marine Riser, ship hull or similar shallow object;

b. Surface-oriented diving from a stage to depth not exceeding 55 m. (± 180 ft.) which permit inspection of sea bottom, re-entry equipment etc., at most drilling locations;

c. Deep diving operations in water depths greater than 55 m. which utilizes a diving bell attached to the surface via an umbilical is lowered to sea floor where, once it is pressurized, the diver can exit and proceed to the job site.

Diving operations beneath ice cover is expected to be also conducted in this area in support of certain activities by CanMar during the freeze-up period.

Eastern Arctic (Lancaster Sound and Davis Strait)

DIAND is currently examining applications for drilling in both Lancaster Sound and Davis Strait areas where water depths range up to 3000 feet.

It is my personal expectation that at least one such operation would take effect in the 1979 drilling season (starting sometime in July-August of that year).

The diving operations required in support of such a drilling program is expected to be limited to SCUBA type operations to inspect ship hull and similar shallow equipment. The operators are expecting to depend on subsea TV cameras to monitor the performance of deeper equipment.

DIAND's Concern with Diving Operations

Naturally our concern with diving operations is for two reasons:

a. protection of human life;

b. inspection of drilling operations to ensure compliance with regulations.

Due to some unfortunate diving accidents lately, DIAND and EMR found it necessary to expand on the somewhat general section included in the draft Canada Oil and Gas Drilling Regulations expected to be promulgated in the near future. For this reason, draft regulations, dealing only with diving operations carried in support of oil and gas activities in the Canadian offshore areas, have been prepared and would be ready for discussion with industry in the near future. A procedure similar to what has been followed with the drilling regulations is expected to be suggested for discussing the diving regulations. Copies of the draft regulations would be sent to interested parties (e.g. Oil and Gas Industry). Diving Companies and other government departments involved in diving operations). A time period would be allowed for careful examination of the regulations and several meetings would follow to examine suggestions and modifications as required.

SEARCH FOR AN ARCTIC SHIPWRECK

By

Dr. J.B. MacInnis and Mr. D. Elsey

SUMMARY

The HMS BREADALBANE Project represents three years of background study and operational planning culminating in a twelve day expedition to the Canadian high Arctic.

In 1975, the author instituted an archival study of Canadian Arctic shipwrecks. The study was carried out with the assistance of Mr. Clive Holland of the Scott Polar Research Institute in Cambridge. Of all the vessels and sinkings investigated, HMS BREADALBANE was considered most likely to justify the cost and effort of a search expedition.

HMS BREADALBANE was an Arctic resupply vessel used in the search for Sir John Franklin. A three masted barque, she was crushed by ice on August 21, 1853 and sank near the mouth of Erebus and Terror Bay. Less than 15 minutes after being holed, she went down in 30 fathoms. In spite of the hazardous ice conditions her captain and crew were rescued by a second ship.

On August 15, 1978, the author took a small team to Beechey Island, N.W.T. for a side-scan sonar and closed circuit television survey of the adjacent sea floor. Co-ordinated by Phil Nuytten of Can-Dive Oceaneering, the search revealed a side-scan sonar target with about a 90% probability of being "a shipwreck". Since no other large vessels are known to have sunk in the area, it is highly likely that the remains of HMS BREADALBANE have been located.

"By herself, the BREADALBANE was not an important ship. She carried no great treasure or bullion beneath her decks. Even with her three tall masts she would have lain unnoticed among bigger Royal Navy ships anchored in the Thames.

"But her sinking occurred at an important point in Arctic maritime history. The Northwest Passage had just been discovered, the search for Sir John Franklin was at its height and on the world's oceans, iron and steam were taking over from wood and sail.

"Fortunately, there are clearly written journals and logs describing the last voyage of the BREADALBANE. They take us back to the 1850's, a period when Victoria England was at the summit of sea power and most of the Canadian Arctic was unknown and uncharted.

"If found, HMS BREADALBANE will be the most northerly shipwreck to be located. Because of the cold, depth and darkness of the waters that cover her, there is every possibility she will be splendidly preserved, a submerged metaphor of another era.

"At the very least, exactly 125 years later, the BREADALBANE is a reminder of forgotten men and ships who were pitted against the world's most hostile environment. Their skills, ambition and courage are vital elements of the Canadian heritage."

(Notes from the author's Expedition Journal, August, 1978)

The search expedition was carried out under extremely difficult weather and sea-state conditions. Floe ice repeatedly blocked the search area, temperatures remained near freezing and the winds occasionally gusted to 40 mph. Of the nine days spent on Beechey Island only three were suitable for small boat search operations.

During the expedition, 8600 feet of 16 mm film was exposed by cinematographer Rick Mason. Sound recordings of the search highlights were made by Bruce Cowardine. The film and sound will be used for a television documentary "Spirit of the Ice Ships".

Consideration is being given to a second expedition in June of 1979. A small camp would be set up on the solid ice south of Beechey Island. Holes would be cut through the ice and the remaining search area would be surveyed with a rotary side-scan sonar. When contact with the wreckage is made, closed circuit television and divers would be used for a detailed survey.

"Shipwrecks are a tangible link with the past. Each ship that sinks encapsulates a way of life, a period and its people, how they dressed, what they ate and the tools and utensils they used."

BACKGROUND

In April of 1975 the author visited Beechey Island and Erebus and Terror Bay, considered to be one of the most historic sites in the Canadian Arctic. The purpose of the visit was the unveiling of a memorial plaque by Prince Charles of England. In August of the same year the author took a six man team to Beechey Island to film the general features of the bay and its surrounding shorelines. A film record was also made of the ruins of Northumberland House, a supply depot built in 1854, and the nearby relics and memorial cairns.

During the August, 1975 expedition, several dives were made to examine water clarity and sea floor conditions. A piece of curved timber, hand worked and containing four copper nails, was recovered. Estimated to be more than a century old, the wood is most likely part of a small pinnace or life-boat. Presently, it is in Ottawa undergoing preservation.

In late 1975 the author initiated an archival study of Canadian Arctic shipwrecks. The study was carried out by Clive Holland, Assistant Librarian of the Scott Polar Research Institute in Cambridge, England. Of all the vessels considered, HMS BREADALBANE, known to have sunk near Erebus and Terror Bay, was thought most likely to justify the cost and effort of a search expedition.

In 1976-1977 the author spent six months as a visiting scholar at the Scott Polar Research Institute. During this period, Mr. Holland located three descriptions of the sinking of HMS BREADALBANE. The reports described the condition of the ship in the ice, its distance from shore and the water depth in which it sank. It was thought that the information, combined with Commander E.W. Inglefield's lithographs, contained enough detail to place a search team within a mile of the wreckage. Consequently, initial plans for a brief and intensive search of the area adjacent to Beechey Island were drawn up.

Early in 1977, Phil Nuytten, President of Can-Dive Oceaneering, agreed to manage the technical aspects of the search. Mr. Nuytten, a recognized authority in commercial diving and search and salvage operations, offered to contribute two members of his staff as well as all the search equipment. This included an underwater closed circuit television system and a side-scan sonar, the EG&G Mark 1B.

Basically, a side-scan sonar is an electronic device or 'fish' towed on a cable behind a boat. The 'fish' emits short pulses of acoustic energy which are projected in fan-shaped beams on each side of the boat's path. Echoes from the sea floor and objects from as far away as 500 meters are picked up by transducers, amplified and then transmitted up through the cable. On the surface the echo signals are electronically processed and presented on a revolving drum recorder. Depending on the range scale used, 50 to 500 meter swaths can be delineated. Thus, weather permitting, it is theoretically possible to search a square mile within a matter of hours.

Once a promising site is located, it is marked and triangulated with surface buoys. A closed-circuit television system and/or a magnetometer can be used to inspect specific areas.

"Arctic mariners of one hundred and twenty-five years ago expressed the mood and values of another century. They were proud, loners, stoic and confident of their pragmatic wisdom. But, like sailors everywhere, they had an exuberance of animal spirits. As rough hewn as the edge of a glacier, they were men governed by iron necessity - and as a result, no details were left to chance."

HMS BREADALBANE

In 1845 Sir John Franklin of the Royal Navy, sailed into Lancaster Sound with 129 men in two ships, the Erebus and Terror. They were the last and the largest of the British Admiralty expeditions to search for the Northwest Passage. Franklin and his men spent the winter of 1845-46 in Erebus and Terror Bay, just east of Beechey Island. In the summer of 1846 the two ships and their crew sailed southwest and disappeared.

Search expeditions for Franklin and his men began in 1847. As the years passed, over 40 ships sailed into the ice of the Canadian Arctic seeking fragments of the enlarging mystery. One of those ships was HMS BREADALBANE.

"The BREADALBANE sails remarkably well and is a good sea boat, not at all too deep, and apparently well adapted for the service on which she is employed." Commander E.A. Inglefield of HMS PHOENIX in a letter to the Admiralty, June 14, 1853.

The BREADALBANE was a hired Navy transport that sailed to Beechey Island in company with HMS PHOENIX, on a voyage to resupply Sir Edward Belcher's Franklin search expedition. Because she was a 'hired' ship, little is known about the BREADALBANE except that she was not strengthened like other Arctic ships. She was a three masted barque, square rigged on the fore-and-main and fore-and-aft rigged on the mizzen.

E.A. Inglefield was in command of HMS PHOENIX. Fortunately, he was a fine artist and illustrator and sketched the BREADALBANE just before she sank.

PLANS AND RIGGING

At the time of writing it has been impossible to locate the exact ship's plans for HMS BREADALBANE. However, it is known that she was a wooden vessel of 428 tons. Her length was approximately 120 feet and she carried three masts of 100 to 120 feet. Her beam was 24 feet and she drew just over 18 feet of water.

Built in Glasgow in 1843, she carried a standing bowsprit and a figurehead carved in the shape of a woman.

"Figureheads were the symbols of the ships whose bows they graced. Most common was a full-length female figure, usually larger than life size. They were almost always made of pine and given a bright paint and gilt finish. Because they were seen at a distance, contours and silhouette were more important than details. Often, one or both breasts were exposed, reflecting the old seaman's superstition that a naked woman was supposed to be able to calm the storm at sea. To be successful the figure had to give the feeling of flying forward, flowing robes were usually added to give a sense of speed."

The BREADALBANE's square stern was decorated with carved mock galleries and two large 'bower' anchors were stowed on her cats-heads. The ship's bell was located just behind the poop deck.

The lines and deck plan of a 400 ton merchant sailing ship, nearest in size to the BREADALBANE, have been proved by Mr. David Lyon, Research Assistant, Department of Ships, at the National Maritime Museum in Greenwich. In addition, Mr. Lyon has provided the rigging plan of a 500 ton ship and the 'shell' expansion for a 300 ton ship. These plans were taken from an 1829 book by Herrerwick, one of the owners of the Glasgow firm that built the BREADALBANE. These plans, unlikely to be identical to those of BREADALBANE are close enough to be of value during a search of wreckage.

THE CARGO

According to the Public Records Office in London HMS BREADALBANE was carrying a full cargo of coal, food and provisions as well as clothes and other stores. In Cork Ireland, Commander Inglefield picked up 20 sheep, five of which he hoped to carry to Beechey Island. (It is not known if the sheep were transported on the PHOENIX or the BREADALBANE. If on the latter, they may have been the only casualties of the shipwreck.)

On August 8th, HMS BREADALBANE arrived at Erebus and Terror Bay. Approximately 130 tons of coal were lifted from the ship up to the flat shore below Cape Riley, about 2.5 miles from Beechey Island. The coal was unloaded in about 30 hours by men from the ships BREADALBANE, PHOENIX and NORTH STAR.

The NORTH STAR was the depot ship of Belcher's squadron and had wintered over in the bay since 1852. By August 16, 1856 packages (probably food, clothing and other supplies), were delivered to the NORTH STAR. Eventually they were to be distributed to the other ships of Belcher's squadron. According to F.H. Hills, Second Master of the PHOENIX, "about 160 casks and packages went down in the BREADALBANE, the rest having been safely landed." He also mentioned that the crew left the ship so quickly that they "all lost a great part of their clothes and some the whole".

THE CREW

"What motivates men to roll and bounce across the North Atlantic and into the polar pack at an average rate of five miles an hour in damp, cold, confined and uncomfortable quarters? Who were these men? And what were they seeking? Why did they undertake the risks of the open sea, the hazards of accident and sickness and the inevitable and exasperating discipline?"

There were twenty-one men signed on board HMS BREADALBANE for the Arctic voyage. Her master John McKenzie, was probably from Glasgow. William Henry Fawkner, whose journals describe the last voyage of the ship, was the Government Agent. Since BREADALBANE was a hired transport his task was to co-ordinate Royal Navy requirements with the day-to-day ship operations. The rest of the officers included the mate, George Bullen, the second mate Robert Wardener* and the Ice Master George Sabestan. The ships clerk was John Palmer, her steward was James Baker the man responsible for the sails, rigging, anchors and cable, the bo'sun, was George Liddle. James Flett was the ship's carpenter and Thomas Rowlands the ship's cook.

"The sailors on board the BREADALBANE, in their tribulation and anonymity, evoke a sense of our common humanity. Stalwart and self-sufficient, little relying on the outside world, they remind us of those romatic heroes we knew in our youth. Their ship, like all ships that put to sea, was a microcosm of the human condition. On board were all the usual contradictions, humour and pathos, beauty and depravity, life and its sudden extinction."

There were ten Able Seamen (AB): Robert Agston, William Dean, James Farringdon, William Ferrier, Charles Haywood, Magnus Johnston, Daniel Keath, Thomas Lambert, George McAires and William Silverlock. The lowest rating on the ship was Ordinary Seaman (OD): G.B. Evens.

"Every new sailor must come to his own terms with the sea. Long night watches under the sky give a quieter mind, anxious hours peering across the ice teach patience and confined quarters below decks are lessons in tolerance. These are things men do not forget. In time, every sailor begins to grasp the simple truth - all wanderers across the sea are brothers."

THE LAST DAYS OF THE SHIP

The Illustrated London News of October 22, 1853 describes the highlights of the BREADALBANE's voyage to Beechey Island. The description, taken from Fawkner's journal, leaves no doubt that the BREADALBANE's sinking occurred at a critical juncture in Arctic history. Some of the important elements include:

a. The return from Beechey Island to England of two of the survivors of HMS INVESTIGATOR. These men had been absent from home for nearly four years, and were the first 'official' discoverers of the Northwest Passage.

b. The disintegration of morale and leadership that was to lead to the abandonment of three British Navy ships. Under Belcher's command, they were the last official Royal Naval effort to locate Franklin.

c. The transition from sail to steam. HMS PHOENIX was an ice strengthened steam ship. Propeller driven, she outclassed BREADALBANE in her capacity to push through thick ice. As Fawkner remarked in his journal, "she had done in a few hours (what) a sailing vessel would have taken weeks to accomplish". Thus, the sinking of the BREADALBANE was a metaphor for the demise of wooden sailing ships.

"The men of the BREADALBANE were part of a nation that brought the concept of sea power to its greatest height. Using the oceans and its sea lanes the English spun a network of trade and investment around the globe. They went wherever they wanted, from the tropics to the Arctic, protected by the long shadows of the Royal Navy."

"Sailors live in a world bounded by the length and breadth of their ship. For the crew of the BREADALBANE it measured about one hundred and twenty-five feet. Certainly there were minor excursions up the masts, down into the hold and perhaps out on to the ice, but for the most part it was a life contained by the main deck and taff-rail. There were other constraints; of naval discipline and the ship's routine, of unruly weather or an angry sea. So the sailor passed his days, hemmed in by nature, his ship and the officers. And the melancholy thought of distance between himself and his loved ones back home."

PLANNING THE SEARCH

In 1961, a field survey of Erebus and Terror Bay was carried out by the Canadian Hydrographic Service. The field sheet, which shows depth marked in fathoms, was used to mark out the boundaries of the proposed search. Using the written reports and the 30 fathom line as guidelines, a two square mile area was marked out.

It was the author's personal conviction that the ship lay somewhere near the junction of the two square mile area. Normally, search patterns overlap and thus the area of highest probability would be covered by two separate sweeps.

The field sheet, proposed search areas and other relevant information were reviewed by P. Nuytten and D. Elsey who concurred that, with the many landmarks prevailing, it would be possible to conduct a rapid and comprehensive search of the two square miles.

With one reservation. Ice conditions and sea state had to be compatible with conducting the search from a 14 foot inflatable rubber boat. The remoteness of the site meant that only an inflatable could be flown in by Twin Otter.

"It is fitting that Devon is the name of the enormous island north of Beechey. In England, the area known as Devonshire, was the home of many of the great mariners, among them, Drake, Raleigh, Hawkins and Frobisher."

PLANNING THE EXPEDITION

As in six previous Arctic expeditions a specific planning sequence was used to raise funds and co-ordinate logistics.

a. A comprehensive proposal was written to describe the aims, steps and implications of the project.

b. A small group of technically competent poeple were asked to donate their time, experience and equipment.

c. A larger group of interested people from the private sector and government were asked for 'in-kind' support, the loan of equipment, reduction of costs, use of accommodations, aircraft and helicopter time, etc.

d. One or two individuals were approached to provide 'core funds', those dollars essential to cover food, travel, freight costs.

As of September 15, 1978 the James Allister MacInnis Foundation had spent $18,000 (this figure includes approximately $8,000 toward the making of the film). The estimated 'cost' of the expedition, including all 'in-kind' contributions, was approximately $66,000.

Some 65 pieces of equipment and 8 men were flown from Vancouver and Toronto to Resolute, N.W.T. and then by twin otter to Beechey Island. The equipment weighed approximately 5,000 pounds. It took many hours work to organize, assemble, pack all this gear and it should be borne in mind that the aircraft did not land at the campsite. The entire load was lifted, pulled, rolled, slid and cursed down a gravel slope across a shale beach into and out of a boat and finally up the beach at the end of the island.

The 65 cases, packs, crates and containers held: 8 sleeping bags, 8 life-jackets, 2 rubber boats, 2 motors, 2 gas tanks, 8 tents, 2 generators, 5 water jugs, camera equipment, sound recording equipment, pots and pans, over 200 packages of freeze-dried food, maps, books, funnels, filters, paddles, a 303 rifle, a 12-gauge shot gun, 3 FM-CB radios, powdered milk, cereal, coffee tea, cheese, nuts, raisins, soup, chocolate bars, spices, toilet paper, 3 survival suits, 4 exposure suits, gloves, 8 down jackets and wind-breakers, two transits, one Coleman stove, two lanterns, one complete side-scan sonar unit, one complete underwater closed circuit television system, marker buoys, cable and more cable, personal clothing boots, a first aid kid, emergency survival gear, and to lighten the mental load a couple of bottles of dark rum and two cases of wine.

"Arctic history, particularly as it relates to the sea, is a look at life at its simplist and hardest. It is a sober recollection of human beings living in private worlds surrounded by a violent nature. Here is no ordinary nostalgia, but a respect for people who lived and worked in circumstances beyond our comprehension".

The expedition was made possible by the enthusiastic sponsorship of many individuals and institutions. The three years of intermittent research and the ten days in the Arctic confirms the philosophy that specific aims of underwater research can be attained by the co-operation and combined assets of a wide range of people. Sponsors and supporters included:

Industrial

Phil Nuytten, Can-Dive Services
Jim Tooley, Nordair
Gordon Harrison, Canadian Marine Drilling
Robin Chetwynd, Chetwynd Films
Walter Bennett, Mercury Marine
Ian Campbell, General Foods
Victor Royce, Rolex Watch Company of Canada
Ernie Herzig, Herzig Somerville

Federal

George Hobson, Polar Continental Shelf Project
Gerry Ewing, Department of Fisheries and Environment

Territorial

Stu Hodgson, Commissioner, N.W.T.
Bob Pilot, Government of the Northwest Territories

Academic

Clive Holland, Scott Polar Research Institute
David Lyon, National Maritime Museum, Greenwich

Non-Profit Institutions

National Geographic Society, Washington

Individuals

Bill Teron, Ottawa
Rick Mason, Toronto
Doug Elsey, Toronto
Jeff MacInnis, Toronto
Bruce Cowardine, Toronto
Maurice Haycock, Ottawa
Chris Teron, Ottawa
Ann Savors, Greenwich
Beatrice Gage, Toronto
Blair Lowe, London
Hoyle Schweitzer, Los Angeles

CHRONOLOGY - August 15-26, 1978

The following account was taken from the journal of J.B. MacInnis and supplemented with information from D. Elsey, R. Mason and P. Nuytten.

August 15th

Doug Elsey, Rick Mason, Bruce Cowardine, Jeff MacInnis and MacInnis the elder, depart Toronto. Joined in Montreal by Chris Teron, fly Nordair to Resolute. Accommodation at Polar Shelf. Organize equipment and prepare for transfer to Beechey Island.

August 16th

Cowardine, Teron and both MacInnis' fly to Beechey Island in a twin otter. Pack ice covers all of Erebus and Terror Bay and most of the search area. Impossible to use Zodiacs to ferry equipment all the way to campsite as planned. Some 2500 pounds of gear are man hauled down to the beach, into one Zodiac, along the shore and up the terrace to the site. Two main tents and three sleeping tents are put up. The search area looks white and grim.

August 17th

Snow and rain today. Haul and ferry in another load from the 'air strip' to the campsite. Pick up water from the creek. Finish construction of camp. Ascend cliffs and walk across the top of the island to Franklin cairn. Rick Mason arrives from Resolute with cameras and another load of gear. Not enough wind to clear the ice from the bay.

August 18th

Rick and Bruce establish 'the film studio' in the green tent. Climb again to top of the island to film the 'big scenics', but got obscures everything. Cold finger numbing winds begin to blow from the north. Film at Franklin's cairn and grave sites. Twin otter arrives with Stu Hodgson, Commissioner of the Northwest Territories, Bob Pilot and others. They have come to visit and work on one of the memorial cairns. Film inside and outside of longhouse tent. Wind continues. Prayerful thanks given that it is from the north, and not the south.

August 19th

At 2 a.m. this morning ice begins to move out of the mouth of the bay. About 1/3 of the search area is now clear. Wind is bitter and cold, 15 kts out of the north. More gear ferried in from 'airstrip'. Doug Elsey, Phil Nuytten and Bill Teron arrive from Resolute. Preparations made to begin the search tomorrow. Late in day search area is over half free of ice.

August 20th

Cold and sunny. Morning used to ready and set up side-scan sonar equipment in the Zodiac. Wind 10-15 kts from north. Search begins after lunch with Jeff, Doug and Phil spending 4.5 hours in the cramped Zociac. They find:

a. Large expanses of empty sea floor;

b. Impressive ice scouring down to 180 feet;

c. A significant 'contact' in about 110 feet.

The object is approximately 35m long and 7m wide. This discovery takes place within 12 hours of the 125th anniversary of the sinking. The 'object' is too vague in outline to give rise to much jubilation.

August 21st

Sunny and calm. Maurice Haycock and George Hobson, Director of the Polar Continental Shelf Project, arrive by helicopter. Rick uses helicopter for one hour of shooting 'location shots'. Search continues. The Zodiac with Phil and Doug along with Chris makes a long sweep east across the bay toward Cape Riley and back. The afternoon search focuses on the 'contact' area. Buoys are dropped with elegant inefficiency by MacInnis and Mason. Shortly after they are carried away by the ice. Several passes are made near the 'contact' and new records obtained. Six hours of searching today. We have our second meal of baked char, a splendid caloric deliverance from freeze-dried food.

August 22nd

Calm. Almost no wind. A few ice pans sail across the search area. Prepare closed circuit television system and underwater light and mounting bracket. Both Zodiacs are lashed together with the generator and film crew in one and search team in the other. Head out to search area about noon. A polar bear swims a warning wake across our bows. Large red marker buoys have been taken out by the ice so 'blind fishing' is the only option with the television. The television camera allows us to look at:

a. a sea floor covered, at 100 feet and deeper, with anemones;

b. many deep ice scours;

c. large rocks and stones;

d. no sign of wreckage.

The evening is spent towing the side scan over the bottom to the west of the contact area. The sea is calm and considerable distance is covered. Both Zodiacs are out on what proves to be the last period of search.

August 23rd

Sunny and relatively calm but ice floes have moved in to cover most of the search area. Go out in both Zodiacs to film the search boat working through the ice. Experience some difficulty in getting boats back to campsite. Phil leaves in helicopter with George Hobson and Maurice Haycock. Begin to pack up, leaving the search gear ready in case the ice shifts. Tomorrow, a late evening, jocular in the extreme, due to the firm commitment not to carry any ethanol back to Resolute.

August 24th

The wind and ice have taken over. Wind 20-30 kts. Sky grey and cloudy. A final look in the Zodiac convinces that the entire search area is locked solid. We decide to break camp: Zodiacs emptied of gear and deflated, generators run dry, extra gas burned off, bags packed, food put away, tents stowed - a 4-hour marathon, just ahead of the wind and the rain. Polar Shelf helicopter drops our gear (thank God) at the 'airstrip'. Two flights later we are all back in Resolute.

August 25th

All day (well, nearly) spent in collecting, sorting, packing, marking, and carrying the gear. Some stays and some goes with us. Depart at 1800 hours on Nordair. South to Montreal, via Hall Beach and Frobisher. Greeted by the Air Canada strike. Sleep in the terminal comfort of Dorval airport.

August 26th

All home except Rick who stays behind to film in Resolute

SEARCH HIGHLIGHTS

"There are times when preparing for an expedition that you experience sudden mental excursions into the future to see things as you hope they will occur. There lies the ship, heeled over on the bottom, in all her broken splendour. But these moments are a deceptive luxury, for anticipation carries with it the promise of dashed hopes."

The 'contact' made with the side-scan sonar has been studied by three sonar experts. All agree that there is a high probability that it indicates a shipwreck. Since there are no known records of other vessels in the area, the tentative conclusions are that there is a 90% certainty that it is the HMS BREADALBANE. (In the event that the ship is

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not found during the next phase of the expedition, the 10% will be used as an escape hatch). The side-scan records will be read by other authorities, including H. Edgerton, of MIT, inventor of the EGG side-scan.

ICE SCOUR

No one expected it. The records confirm that the sea floor down to 180 feet and deeper was covered with deep scour marks. When first seen, on August 20th, hope of finding the wreckage plummeted. However, some glaciologists suggest that the ice scour occurred prior to the sinking, perhaps as many as 10,000 years ago. Further work will be carried out to clarify this issue as soon as possible.

LIFE

The water covering the 'contact' was extremely clear. With the television camera the sea floor could be seen at 80 feet, even when the underwater light was turned off. The bottom was covered with anenomoes that crowded every square meter. There was no evidence of sediment.

NEED FOR A SECOND EXPEDITION

A review of the expedition and its findings has led to the tentative conclusion that a second expedition is required. Phase II would see a four man advance party flying to the site in May, 1979. Holes would be drilled through the pack ice and a rotary side-scan sonar used to confirm the location and status of the 'contact'.

If warranted, divers would be brought in one month later to survey and film the wreckage. Since this is complex and costly, the advance party is a necessary prelude.

In the meantime, all aspects of the August expedition will be reviewed. Particular emphasis will be given to the side-scan records and the ice scour information.

IMPLICATIONS

Canada has the longest ocean coastline, most of it in the Arctic, of any nation. The tangled maze of islands and waterways between Greenland and Alaska were initially settled by ancient Eskimos. Later, during the past 400 years, they were 'discovered' by Europeans, Canada's seafaring ancestors, who ventured into the pack ice in small, wooden sailing ships.

We know very little about these men. We do know that most of them were from England and we also know that they were mariners of the highest quality whose actions were guided by the dictum:

"Whosever commands the sea commands the trade. Whosoever commands the trade of the world commands the riches of the world, and consequently the world itself."

Sir Walter Raleigh wrote these words back in the 16th century, about the time that Martin Frobisher became the first man to 'discover' the Canadian Arctic.

By 1815 Raleigh was proven right. The English had gained control of the seas; before the end of the century they would rule all of Australia and New Zealand, India, half of Africa and the northern half of North America. Thus was created the richest and most powerful empire the world has ever known.

But what about the men who manned the ships that sailed west and *north into the Arctic? What were they like in manner and appearance?* How did they conduct themselves inside wooden walls surrounded by ice? What clothes did they wear and what seaman's tools did they use?

The remains of HMS BREADALBANE may prove some of the answers. Because she sank so quickly, the men left behind most of their personal effects and almost all of the equipment needed to operate a three masted ship. These relics are not gold or silver, but a different kind of treasure - everyday commodities essential for survival on the polar ocean. On board an Arctic ship nothing was trivial. What lies on the sea floor south of Beechey Island are more than simple utensils. They *are the working currency of men under canvas.*

"Afterward, looking back, you are as impressed as much by what the Arctic is not, as by what it is. It is not warm, it is not human, it is not occupied, except by emptiness and memories."

PUBLIC AWARENESS

The sinking of the BREADALBANE occurred at a critical moment in maritime history. Around her departure swirl the mists of the lost Franklin expedition, and the failure of the greatest maritime search in *naval history - to find Franklin's ships Erebus and Terror.* It was a time of excitement and despair; Belcher lost three of his ships to the ice and HMS PHOENIX carried home to England the first men to cross the Northwest Passage.

PHOENIX and BREADALBANE were symbols for the end of an era. Both ships struggled against the same ice, the PHOENIX towing the BREADALBANE. Only the one with the iron hull and steam survived.

Few Canadians are aware of the significance of maritime history. HMS BREADALBANE represents a time when personal initiative and enterprise *were paramount values. Without these men and their small ships,* the story of northern Canada would have been significantly different.

We are a nation seeking to know our origins so that we can control our future. A vital part of our past is the 'heroic age' of Arctic maritime history. The search for HMS BREADALBANE and the story surrounding it, proves an opportunity to bring that period of our history to life.

Eight thousand feet of film and many hours of sound recordings were taken during the August expedition. The footage is being edited into a 'fine cut' and will be supplemented with additional archival material. This material will be incorporated into a one hour television special, "Spirit of the Ice Ships".

"At the end of every expedition you find that something is troubling you. It has nothing to do with success or failure. No, it is a more insidious thing, the disquieting realization that your goal has been achieved and is gone."

AUTHORS' NOTE

The presentation made by the authors is highlighted in the preceding extracts from the technical report written by Dr. MacInnis. However, nothing can replace the outstanding 'podium presence' of both men, particularly the warm, obsidian-smooth humour of Mr. Elsey. The passages in italics are extracts from Dr. MacInnis' personal journal kept during the expedition.

"ARMED FOR DEEP WATER"

By

Mr. P. Nuytten

Can-Dive Services Ltd.

The following is a narration of the film as presented at the Third Canadian Diving Symposium.

Scene 2

This is the drillship - "Ben Ocean Lancer" - it's carrying out exploratory drilling in search of oil beneath the sea floor off the Canadian Province of Newfoundland. The date is August, 1978, and the "Ben Ocean Lancer" is on location in two thousand feet of cold, North Atlantic water.

The Captain of the Ben Ocean Lancer controls his vessel from this space-age bridge...hundreds of pulses of information are fed into the complex control system every minute...for the "Ben Ocean Lancer" is not held to the sea floor by conventional anchors and chains...it manoeuvres on station, by means of huge thrusters. These thrusters respond to computer commands and hold the ship precisely in position, adjusting continuously for wind, waves and ocean currents. This system is called dynamic positioning.

Scene 3

These seagulls show a gourmets delight as they forage in the upwelling wash created by the large dynamic positioning thrusters.

Scene 4

The members of the Ben Ocean Lancer drilling crew are transported to and from the vessels location, 50 miles offshore, by helicopter...this is their worksite.

Scene 5

A small worksite..on a large ocean.

Scene 6

The worksite for the Oceaneering crew is a little further yet, two thousand feet below the Ben Ocean Lancer. Our "helicopter" is this manipulator equipped thruster bell called the Ocean Arms 1.

Ocean Arms 1 is shown here surfacing from a working dive...once the bell is secured in its storage position, the Oceaneering technicians will carry out post dive maintenance and post dive systems check out... although the "Ocean Arms 1" is tethered to the drill ship by means of a heavy strength wire...it is equipped with manoeuvering thrusters, not unlike the dynamic positioning thrusters on the Ben Ocean Lancer, and it can "fly" on the end of its tether wire in a manner similar to that of a conventional submersible. The Ocean Arms 1 is fitted with battery pods to provide the power for thrusters, underwater lights, close circuit television cameras, a host of on board instrumentation, and most important, the heart of this underwater work system...the G.E. force-feedback manipulator.

Once these technicians have completed their task of recharging the batteries the Ocean Arms 1 will be ready to dive again, only this time, we'd like to invite you along to our worksite...on board the Ocean Arms 1...Oceaneering's latest deep water work system.

Scene 7

We call the Ocean Arms 1 a deep water work system because that's precisely what it's designed to do...carry our work in deep water. These "roughnecks" are carrying out the basic work that the "Ben Ocean Lancer" was designed for...the work of drilling an exploration hole in the sea floor. The entire drilling vessel, its complex systems and sub-systems all culminate in the work that these men are doing..."making hole"...the bottom line of the drilling vessel.

Doing work...on the bottom...in deep water is our bottom line. Like the drilling vessel, it takes a lot of expensive, sophisticated equipment to accomplish that end...to get Oceaneers to the bottom..perform effective work...and get them back again safely. Oceaneering International was formed as a deep water support company. Over the past decade we've become known for many diverse capabilities but we've never lost sight of the fact that our speciality - our unique skill...lies in "arming our clients for deep water"...however deep that may be.

Scene 8

This is the centre well or moon pool that we'd be diving through... and it gets plenty rough..but Ocean Arms 1 can handle it. Well, that's enough of a commercial. Let's have a look at Ocean Arms 1...it's a lot of technology crammed into a small package! Let's see what it was designed to do.

Scene 9

The essential feature of the Ocean Arms 1 is the G.E. force-feedback manipulator. This system was perfected by the General Electric Comapny and, as the name implies, it contains a unique patented feature.. force feedback, unlike conventional manipulator arms, the operator using

the G.E. arm actually feels the object he is grasping or working on. In addition, the spatial orientation of the arm is such that the entire arm exactly duplicates the master control motions of the operator. With conventional manipulators, the functions of the remote arm are controlled by switches and levers - with the G.E. arm...you simply do as you've always done...when you reach out - the arm reaches out in direction proportion and in exact duplication. If you were going to open or close this valve...you could grasp the handle or you could simply do it with one finger...because you can feel it! The operator can feel this valve handle also. The things you can do with this unique arm are limited only by your imagination and ingenuity...in making up jigs or adapting conventional surface tools to do a specific task.

Scene 10

Well, it looks like everybody's ready - so come on aboard - your pilot is John Fike, the arm operator is Tom Pado...both are professionals - both are Oceaneers! The first order of business is a thorough systems check...all of the various systems and sub-systems are cross checked with the surface technicians...and everything checks out go...The Ocean Arms 1 is held rigidly to a track system which runs vertically down the sides of the moonpool. The carriage around the bell prevents it from being moved about by the wave force. Once the bell is below the rough surface of the moonpool, the carriage holding the bell will stop at the end of its vertical tracks and leave the bell free to be lowered to the sea floor by its tether cable. The launch and recovery carriage will remain at the end of the tracks until the ascent, where it will once again hold the Ocean Arms rigidly for the trip through the interface in the moonpool.

Scene 11

That's the inside wall of the moonpool going by as we descent... and there's the bottom of the hull of the Ben Ocean Lancer. We have to stop here in shallow water while John Fike and Tom Pado carry out an in-water systems check. They want to make sure that nothing was damaged in the interface...and to confirm that all exterior systems have maintained their water-tight integrity. The close circuit television system is turned on...and checked on the monitor inside the bell as well as the monitor at the surface station. The surface crew will be able to see exactly what you see via the television camera mounted outside the bell. The bell is free from its launch carriage now and the thrusters are tested by energizing first one side, then the other...everything is working well. Fike gets on the radio phone and tells the surface that all systems are checked out...he say, "we're ready to begin descent". The surface technician says, "Roger, that, OA 1 - we're starting descent."

Scene 12

That's the marine riser...it's the only link that the drilling vessel has to the sea floor. Inside this riser, the drill string is rotating and boring into the bottom. The riser is checked out on the

sonar screen inside the bell. If currents should move the bell out of the range of visibility, the riser will show up clearly on the sonar and the Ocean Arms 1 can be powered back into position...now we're heading down again.

Scene 13

It's going to be chilly on the bottom - the water outside isn't much above freezing...well, no point in getting cold...what's that? Yeh I guess I should have told you...it slipped my mind!

Scene 14

Those pods around the riser are buoyancy packs made of a special syntatic foam. They help minimize the tremendous weight of thousands of feet of steel pipe - the depth here is approaching 1,800 feet.

John Fike is operating the thruster control box. You can move it around with you so that you get just the gentle touch you require to put you where you want to be...the thrusters can rotate the bell 360 degrees as well as fly it straight ahead or reverse.

We'll just manoeuvre the bell around a bit and start to head over to the stack...depth here is about 2,000 feet - is damn deep but this system is rated to 3,000 feet.

We made a certification dive for Lloyd's of London just last month to 3,000 feet. Our bell one will be rated to 4,500 feet!

Scene 15

And there's the stack...boy, underwater television was never like this. You can see virtually every nut and bolt...you get the feeling that you can reach out and touch the stack...and, of course, with the G.E. Arm you can do just that...reach out and touch it!

The bell is stabilized and the arm turned on...and Pado reaches out for the stack...not much of a trick, I suppose, except that it happens at 2,000 feet.

The jaws grip one of the bolts securing the end cap - the operator can feel if it's tight or not.

There's the sea floor and that's the conductor pipe going into it. Above that, is the guide base and mandrel and above that...the stack itself.

By using the thrusters we could come right up and bump it, if we wanted to.

Scene 16

The bell-mounted T.V. camera is on a pan and tilt mechanism that can be controlled from inside the Ocean Arms 1. The operators can move

the camera and it's light and transmit the video signal to the surface station. The monitor in the bell allows the bell operators to check the picture that the surface is receiving.

The picture can be video taped to provide a permanent record of inspection - but most importnat, the drilling crew can see first hand and in real time...any problem areas can be discussed at length, with the bell crew, and a collective decision made on what action should be taken.

The surface technician reports that they are receiving a good picture. When the Ocean Arms 1 system was first installed, the drilling crews clustered around the T.V. monitor to see the incredible variety of marine life...but the schools of fish soon became common place and are ignored except when they get in the way of the T.V. picture.

Scene 17

All of the reports from the bell are monitored and tape recorded. This commentary, when coupled with the video tapes and the operators personal observations, will give the drilling superintendent a clear idea of the condition of the entire bottom assembly...critical knowledge that is difficult to get with other systems.

Scene 18

The inspection is over and we're starting to head back up to the surface. All systems functioned perfectly...another routine dive for Ocean Arms One.

Scene 19

The strength wire spools evenly onto the winch drum. An automatic tensioning system ensures that the wraps are laid on, precisely every foot of the marine riser can be inspected on the ascent, if required, the bell can fly around for a clear look at the opposite side.

Scene 20

When the bell reaches the bottom of the Ben Ocean Lancer, it latches into the launch and recovery carriage and is held rigidly. Again, notice through the hemisphere port, the water at the interface washes up and down but the bell stays relatively still as it's winched up the vertical moonpool rails.

Scene 21

Hoisted up into the storage position...and another dive has gone off well - you enjoyed it? That's great! Fike looks pleased...so does Pado...We're the professionals from Oceaneering and we're getting better every day.

DELEGATES ATTENDING THE 3RD CANADIAN DIVING SYMPOSIUM

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The following addresses are of companies, organizations or of individuals who attended the "Second Canadian Diving Symposium" held at DCIEM 31 October - 1 November, 1977, and were unable to attend the Third Symposium. These addresses are published in an attempt to broaden the channels of communication within the Canadian diving community. The accuracy of this information cannot be vouched for.

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